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Standard Program for Impact Assessment
Phase 1. Ichthyoplankton Sampling

Rhode Island Univ., Kingston. Graduate School of
of Oceanography

Prepared for

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Martin A. M. Hyman
Ernesto Lorda and Saul B. Saila

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Division of Marine Resources
GSO-URI Kingston, RI 02881

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16. ABSTRACT

Sampling variability fo ichthyoplankton at a single sample site was investigated. The major sources of variance were identified as seasonal (differences over days), diurnal, tidal and gear. Patchiness of plankton was not recognized as a significant source of variance in this study. No relationship between net avoidance and velocity of two was demonstrated. However, different avoidance responses from fish larvae and zooplankton were found. The above-mentioned methodology is and results are described in detail. The mechanical flow meters used were found to perform in an acceptable fashion. Sampling 100 m^3 of water is inadequate to collect density data for some species.

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A STANDARD PROGRAM FOR IMPACT ASSESSMENT
PHASE I - ICHTHYOPLANKTON SAMPLING

by

Martin A.M. Hyman
Ernesto Lorda
Saul B. Saila
Marine Experiment Station
University of Rhode Island
Kingston, Rhode Island

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Project Officer

Alan Beck
U.S. Environmental Protection Agency
Environmental Research Lab
Narragansett, Rhode Island 02882

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Division of Marine Resources, Graduate School of Oceanography, University of Rhode Island, contributes to the multidisciplinary focus through programs engaged in:

- studies of environmental contaminants in the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources

The main report and 4 appendices which follow relate to monitoring strategies for ichthyoplankton. These involve quantitative assessments of the effects of environmental contaminants on the early life history stages of important marine organisms. The findings from this study are expected to aid in more effective assessments of the effects of perturbations on certain aquatic organisms found in the plankton.

Appendix V of the report deals with benthic organisms from both a field and laboratory point of view. Appendix V is divided into three distinct manuscripts. The first of these defines a transect study of fine-grained sediments in Narragansett Bay and the results suggest that sediment interface camera photographs, and acid-leachable metals with sediment granulometry were useful for assessing the condition of benthic communities. A second manuscript deals with field observations (SCUBA) of the stomatopod, *Squilla empusa*, indicating it is an active burrowing animal which may significantly affect sediment-water exchange in estuaries. The final manuscript, which considers the functional significance of benthic macrofauna, from a laboratory study, suggests that the macrofauna affect transfers of chemicals across the sediment-water interface by increasing surfaces for bacterial reactions, by cropping the bacteria, and by enhanced mixing of the sediments chemically.

Appendix V addresses benthic community processes, and considers measures of benthic community health and metal fluxes as affected by macroinvertebrates. This supplements the plankton assessment capabilities and provides capability for an ecosystem approach to evaluating impact of environmental pollutants. Combined investigation of water column fauna coupled with a study of benthic processes are essential to an assessment of the ecosystem.

Walter Gray, Director
Division of Marine Resources
Graduate School of Oceanography

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ABSTRACT

A carefully planned and executed sampling design to estimate components of sampling variability for ichthyoplankton at a single sample site was demonstrated. A stepwise procedure was utilized to identify and evaluate major sources of variability, which included seasonal, diurnal, tidal and variability due to non-uniform sampling gear and techniques. A non-linear covariance analysis procedure was utilized in isolating sources of variability in ichthyoplankton density data. The major sources of variance were identified as seasonal (differences over days), diurnal, tidal and gear. Patchiness of plankton was not recognized as a significant source of variance in this study. No relationship between net avoidance and velocity of two was demonstrated. However, different avoidance responses from fish larvae and zooplankton were found. The above-mentioned methodology is and results are described in detail. The mechanical flow meters used were found to perform in an acceptable fashion. Sampling 100 m^3 of water is inadequate to collect density data for some species.

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SECTION I

INTRODUCTION

The pressing need for enlightened management and regulation of estuarine ecosystems is made more critical by the difficulty of predicting the consequences of man-induced perturbations. An estuary is a very complex system with large numbers of biological, physical and chemical components. The physical variables vary with time at a fixed point in space mainly as a result of water movement of various scales according to the principles of dynamic oceanography. Biological variables and some chemical variables vary as a result of the same processes, but also according to principles inherent in biological material. These may be independent of physical water movements, or may enhance or reduce their effects. Interactions among these components are characteristically nonlinear and involve intricate feedback loops.

An adequate or comprehensive survey of attempts to model ecosystems or even specific estuarine ecosystems involves much more effort than is available for the purpose at hand. Suffice it to say that most predictive modeling efforts to date have involved viewing ecosystems as consisting of interconnected compartments (sometimes of several component species) and in the flow rates between compartments. The ecological processes going on within the compartment among various species are assumed to average out into some fairly simple behavior for the compartment.

The complexity of estuarine ecosystems and the growing need for proper management decisions and regulations have placed a high priority on large-scale integrated models. One example of a complex situation model for Narragansett Bay is the recent work by Nixon and Kremer (1975). The practical effectiveness of predictions from a model, such as the above-mentioned, is limited by the size of the model grid as well as by the accuracy and precision of the model parameters and state variables, among other things. In general, it appears that ecosystem level models, as currently conceived, are able to predict with reasonable fidelity only the consequences of very gross types of perturbations, and cannot be used for practical decisions which are site specific.

Recognizing the limitations of these ecosystem models, environmental impact studies have developed historically into the establishment of a so-called baseline and a so-called monitoring program. As currently executed, baseline studies usually consist of a sort of "snapshot" - a short term picture of an environment - which is variable in both space and time and with little indication of the magnitude of these scales of variability. The monitoring program has evolved into a systematic collection of data over time. Regrettably, in the latter case very little critical information on the

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sampling interval, the minimum desired length of the time series record or the nature of sampling variability is presently available.

It is suggested that among the host of economic, political, logistic, and statistical problems involved in the establishment of a standard program for environmental impact assessment, the latter two have received insufficient attention, in spite of their potential value.

Relatively little has yet been done in utilizing the principles of experimental design in sorting out effects of spatial and temporal variability as they affect responses of organisms.

In general, it is apparent that the intended use of a particular data set will determine a particular sampling program, and no arbitrarily drawn system for sampling will be suitable for monitoring. The reasons for this include the fact that a sampling program for a particular experiment involves several factors, among which the sampling rate, the duration of individual observations, the accuracy and precision of observations, as well as the accuracy and precision of timing (synchronization) are important.

In summary, it is suggested that a successful environment impact assessment program is predicated on a sequence of carefully planned experiments designed to answer specific questions, rather than a general measurement system. This carefully planned standard program can then be used for establishing suitable guidelines for more routine types of assessment.

In order to better assign sources of variability in ichthyoplankton surveys an intensive sampling scheme was proposed for a single site. It was the purpose of this study to attempt to work toward producing a standard program for ichthyoplankton sampling. By being better able to assign variability to various effects, as opposed to lumping into an overall error term, data will be of an overall higher consistency and thus in general more useful. Specifically once this variability is better understood, any modeling effort should prove more productive. The application of linear model analysis to this problem is considered in Appendix I. However, some evidence in the literature (Sameoto, 1975) of important variability due to the response of plankton to tidal cycles implies that analysis of variance based only on linear models may prove to be inadequate. This aspect of the analysis of the variance of planktonic organism abundance is investigated in this study, by means of both spectral and harmonic regression analyses.

SECTION II

CONCLUSIONS

Major sources of variance were identified as: seasonal (difference over days); diurnal, tidal, and those due to non-uniform sampling gear and techniques. These may account for any temporal variability in the abundance of ichthyoplankton. Although not a major source, wind may be a possible origin of variance. Patchiness was not recognized as a significant source of variance. However, this conclusion only applies to data collected with oblique tows as in this study.

No avoidance/velocity relationship could be detected. However, because of the fairly constant tow velocities, it must be recognized that this study cannot be conclusive as to whether or not differences in tow velocities are a major source of variation. Evidence of different avoidance responses from fish larvae and zooplankton was found.

The laboratory procedures utilized by Marine Research Incorporated for this study proved to be acceptable for ichthyoplankton surveys.

The mechanical flow meters used in this study proved to be acceptable for plankton surveys. However, standardized flow meters should be used simultaneously in both nets.

Sampling 100 m^3 of water is not sufficient to collect representative data on the densities of some species found in Narragansett Bay.

When the vessel is stopped between legs of a double oblique tow, the nets do not fish while being lowered to the bottom, and thus the sum of tow times for both legs is the best estimate for total tow time.

Analysis of data collected from estuarine environments cannot be limited to linear analysis of variance. The nonlinear covariance procedure developed proved to be adequate in isolating sources of variability in ichthyoplankton density data. Estimates of mean densities of ichthyoplankton computed by traditional methods are biased by the nonlinear response of the organisms to tidal and diurnal cycles. New estimation techniques investigated avoid this type of bias.

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SECTION III

RECOMMENDATIONS

If comparison of relative abundances is the goal of a survey, mechanical flow meters, which have been checked for consistency, are adequate. If in addition, the purpose of a study is to estimate absolute abundance, the meters used must also be calibrated.

For a successful statistical analysis, it is desirable that the critical species occur in at least 50% of the samples. A cluster analysis performed on a preliminary survey would be useful in identifying indicator species, on which to base empirical estimates of the minimum volume of water to be sampled. This minimum volume of water, together with the depth and vessel speed will determine the number of legs (bottom to surface) to be taken in each oblique tow. To insure that tows are consistent and that they sample the water column uniformly, each leg of an oblique tow should begin with the vessel stationary, and with the gear on the bottom. The best estimate of fishing time is then the sum of the tow times for each leg, neglecting the time required for the gear to sink to the bottom for the starting point of the next leg.

Gear (i.e. nets and meters) and towing techniques should be standardized and documented.

Every effort must be taken to limit errors in counts and identification. A minimum of 20 samples, or 10% of the total samples, should be recounted to check for laboratory errors.

In order to successfully test for temporal variability in abundance, the organisms' nonlinear response to diurnal and tidal cycles should first be removed by means of harmonic regressions. Subsequently, linear responses can be tested by means of standard models of analysis of variance, preferably of a multivariate type. The overall response would be tested over groups of species clustered according to similarity in avoidance response. The application of this non-linear covariance analysis requires that the data be collected at specific frequencies to insure that the maximum periodic responses are sampled.

For a long term estuarine monitoring program, seasonal trend control stations should be established and sampled weekly. Different frequencies may be necessary depending on local conditions previously determined. Other stations in the area could be sampled as often as possible under the constraints that the samples at each station be taken exactly at high tide

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and low tide and at noon and midnight. In addition, hourly samples for a 24 hour period should be taken monthly at the control stations in order to recompute the parameters of the periodic function. Integration between the desired points in time of the periodic functions should be used to compute unbiased estimates of the mean abundance of species known to have significant responses to diurnal and/or tidal cycles.

In order to collect data adequate to cluster species by their typical avoidance response, it is recommended that an experimental survey be designed using a large range of tow speeds. Analytical techniques developed in this study have shown that it is possible to design a test to determine significant differences in avoidance response to various tow velocities if adequate data exists.

In order to minimize sample analysis costs an experiment should be designed to determine the relationship between counts and biomass for estuarine species over various stages.

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SECTION IV

DATA COLLECTION: MATERIALS AND METHODS

A single sample site was chosen in West Passage of Narragansett Bay, in order to intensively look at within station variability. Because this was an "average" site, it is felt that the results which apply to this site will be directly applicable to any sampling program. While interstation variability is important, and assumed to exist, it was not within the scope of our study. The sampling site chosen was 1/4 mile off the southwest tip of Prudence Island (Fig. 1). The area has a relatively uniform depth of approximately 50 feet and is not located in a high traffic zone. The 50 foot depth permitted 4 minute duration double oblique tows to be taken. The chosen site was marked by bearings, fathometer traces and buoyed to insure geographic repeatability. This site corresponds with station #158 of Marine Research Inc. (Marine Research Inc., 1974).

Sampling was conducted on four days, hourly for 24 hours. Each hour two tows were taken, one with the tide and the other against it (i.e., one north and one south). A total of 335 samples were taken. Although problems were encountered on day one, on each of the subsequent three days virtually complete sample sets were taken. Consequently for the purpose of analysis only 275 samples were used. The initial design called for sampling over a two week period; however, the program did run over into a third week. Samples were taken beginning at 8 a.m. for 24 hours on the following days: 24 June, 28 June, 1 July and 7 July 1976. The last three days comprise our data set.

The sampling gear chosen for the study were 60 cm Bongo nets (McGowan and Brown, 1966), both sides containing 505u mesh. For a complete description of this gear see Posgay and Marak (In Press). Due to the large mass of historical data with this gear it was felt that this was an appropriate starting point, in spite of recent additions to the gear collection. It was expected that the two net systems would produce replicate tows, however A-B variability was measured. Two General Oceanics flow meters were used*; one mounted inside one of the nets and the other external to the pair (Fig. 2). For all practical purposes this meter is the existing industry standard. In addition, a Cushing dual axis electromagnetic current meter with deck readout was incorporated into the gear.*

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* Use of trade names does not imply endorsement of the manufacturers or their products by the authors or the University of Rhode Island.

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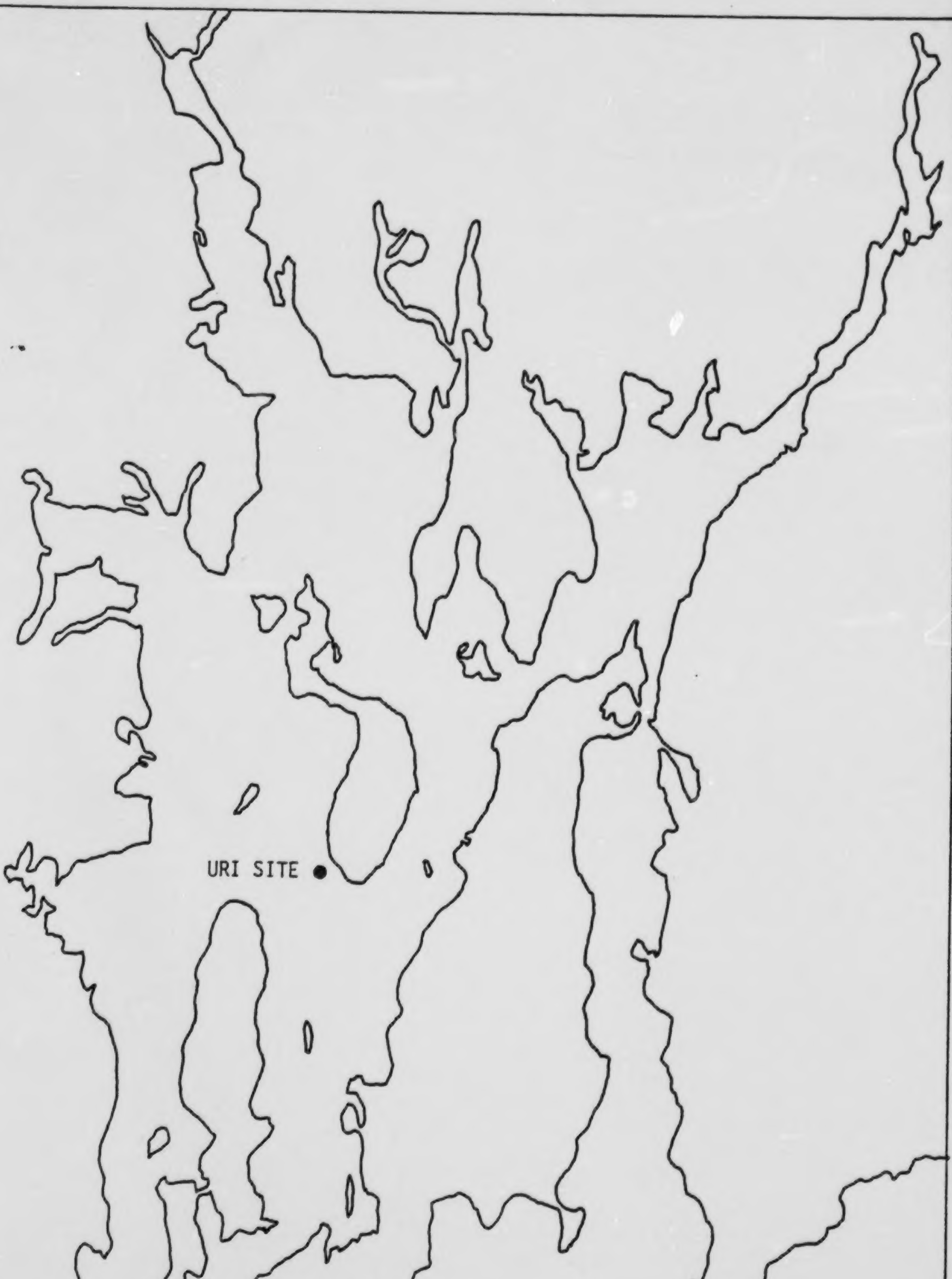


PLANKTON SAMPLING PROGRAM
JUNE-JULY 1976

FIG. 1.

In the original sampling design it was proposed to compare the results obtained from an electromagnetic current meter and General Oceanics flow meters. It was initially felt that the GO meters were a questionable source of volume information. The EM vs. GO meter comparison proved to be impractical. Several successful tows were made with the EM internal to the nets; however when placed externally an irreparable loss of cable continuity resulted in premature termination of the experiments. This was not correctable within our sampling period. It was, however, determined that the nets fished positively throughout the initial tows and did not backwash at any time. Further, fishing between tows was negligible such that volume data are an accurate representation of tows. As a result of the EM failure the GO meters became the sole source of volume data. Based on the method of operation only volume data and average speed are obtainable from these units. The meters did prove, however, to be remarkably consistent. Three meters were used, rotated each eight hours to check for meter bias.

In conjunction with the sampling program various auxiliary data were collected. Ambient light was measured by a standardized light meter reading taken in a northerly direction 30° over the horizon. Cloud cover was estimated in a standard manner as was wind speed. A water temperature profile was taken hourly.

The platform used for sampling was the University of Rhode Island's R.V. Dulcinea, a 39 foot converted U.S. Navy utility boat. Engine RPM's were maintained constant to eliminate differential organism response except as it related to tidal and wind effects. Gear was lowered to just above the bottom with the vessel at standstill (Fig. 3). When an appropriate length of tow wire was let out the tow began. Attempts were made to maintain average vessel speed at 2.5 knots (1.25 m/sec). This technique varies from traditional sampling with Bongo nets in that the vessel is stationary when the gear is deployed, thus "fishing" does not begin until desired and the meter readings better reflect tow period. Checks made with the electromagnetic meter showed that this technique produced a uniform tow velocity. A recovery rate of 0.33 m/sec was used, based on the MARMAP program of the National Marine Fisheries Service (Jossi et al., 1975). This resulted in an average net velocity of 1.6 m/sec. For each tow both nets were washed in a uniform manner and the samples preserved in 5% buffered formalin.

All the samples were transported to Marine Research Inc. for the purposes of identification and counting. To determine subsampling error 10% of the samples counted entirely, one-third of these to come from sparse samples, one-third from intermediate samples, and one-third from dense samples. For purposes of this check, density were estimated by MRI personnel. In addition, 10% of the samples were recounted to evaluate operator error. Finally, in addition to organism counts, biomass estimates were computed for each sample using volume displacement. The samples were returned to this laboratory sealed in preservative for purposes of archiving. The samples were analyzed for ichthyoplankton eggs and larvae, and zooplankton. It was realized that this gear was not efficient for zooplankton due to mesh size and design but it was felt that this lack of efficiency was uniform over the sampling period and thus would give some indication of variability if even only in a relative sense. Because the goal of the

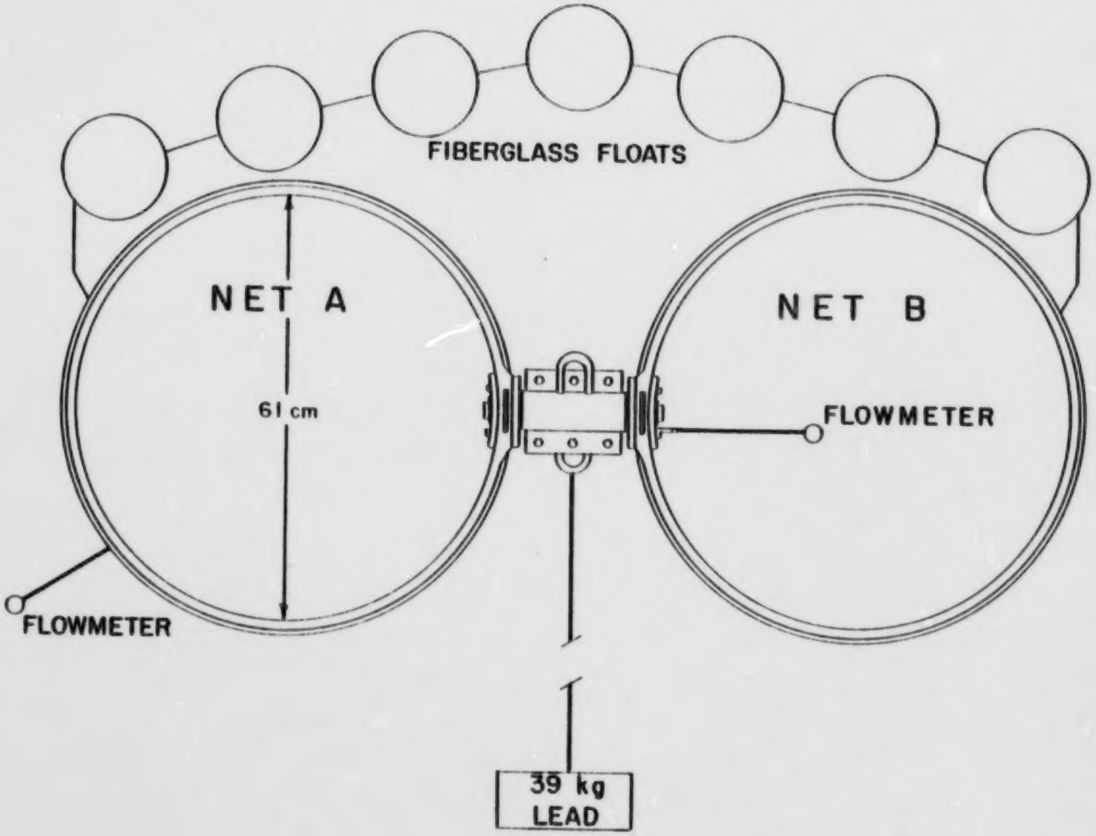
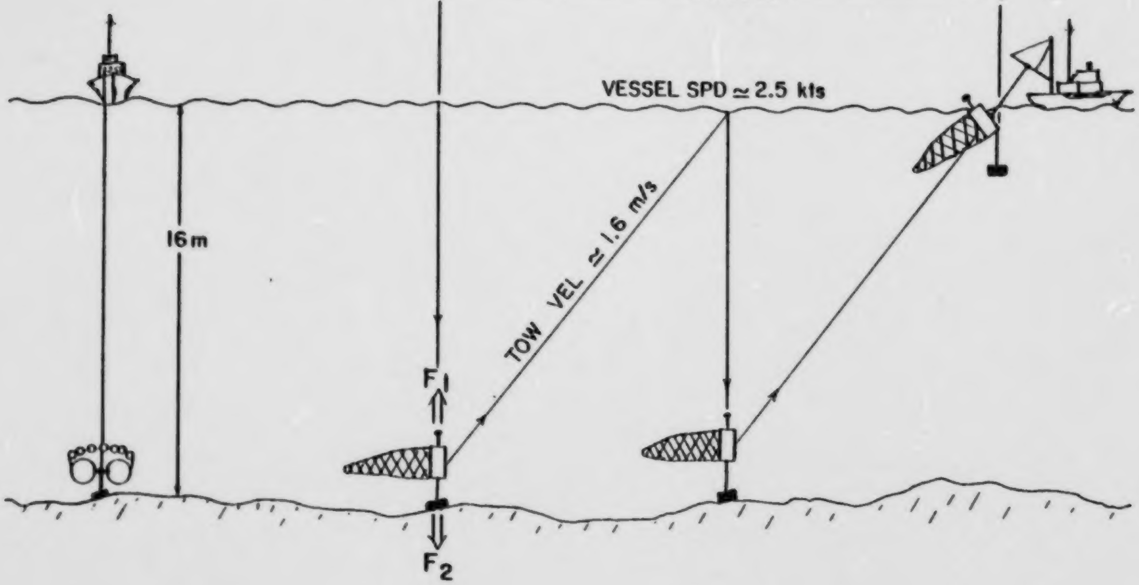

FIBERGLASS FLOATS
NET A
61 cm
NET B
FLOWMETER
FLOWMETER
39 kg
LEAD

Figure 2


≃400m
VESSEL SPD ≃ 2.5 kts
16m
TOW VEL ≃ 1.6 m/s
F_1
F_2

F_1 = BUOYANCY From FLOATS
F_2 = 39 kg (Lead depressor)

$F_2 > F_1$ TO SINK GEAR
$F_1 >$ Submerged total weight of
Gear without Lead depressor

Figure 3

project is to develop a standard program for sampling, it was felt that as a beginning, existing techniques should be evaluated. Consequently, it was determined that Marine Research should apply their normal laboratory procedures. These are described in Appendix II.

The data collected were separated into two categories: 1) physical data; and 2) species counts. The species counts were further separated into three classes: ichthyoplankton eggs, ichthyoplankton larvae, and zooplankton.

For each sample, the number, hour, tow direction, wind speed, surface temperature, mean water column temperature (weighted), bottom temperature, water level function, light intensity, tidal factor, inside volume, outside volume, time of first oblique tow, time between tows and time of second oblique tow were recorded. With the exception of the water level function and tidal factor each parameter is self-explanatory. The water level function and tidal factor are computed from the times and heights for the high and low tides for those days. Times and heights were corrected for Prudence Island (Table 1).

The water level function is defined as

$WL = f(t) = am \cdot [(\sin t) + 1] + min$ where:

WL = water level

t = point in time expressed in radians or degrees

$am = 0.5$ [tidal amplitude]

min = WL at low tide [minimum water level]

max = WL at high tide [maximum water level]

so that:

$$am = \frac{max - min}{2}$$

The tidal factor is formally defined as the instantaneous rate of change of the water level in meters per unit time. It is the first derivative of the above function, so that:

$TF = f'(t) = \frac{dWL}{dt} = am \cdot \cos t$ where:

TF = tidal factor

Negative values correspond to ebb tide or southward flow.

Positive values correspond to flood tide or northward flow.

Zero corresponds to slack tide.

All the physical and tow data were stored in a disc data set within the University of Rhode Island's IBM 370 computer system, labeled "TOWDATA". In addition, Appendix III includes tables and plots describing the water temperature and tidal cycle data from the three sampling days. The counts of the species identified in the samples were also stored in three separate disc data sets labeled: "FISHEGGS", "FISHLARV", and "ZOOPLANK". Computer listings of the above mentioned original data sets can be found in Appendix III.

ANALYSIS OF PHYSICAL DATA

In cases where high accuracy in computing volume filtered is sought, calibration of each meter in a wind tunnel, flume or in the field is required. However, unless large errors are found in the measurement of the volume filtered, for this type of field work good repeatability is by far the most critical feature of a flow meter. In terms of the statistical analysis of biological data, usually subject to large variability from other uncontrollable sources, every effort should be made to avoid the introduction of new variability. A consistent small error in the reading from a particular flow meter does not represent additional variability in a statistical sense. When several flow meters are used, care must be taken to insure that there is no bias among them.

The three mechanical meters used in this study were compared to an electromagnetic flow meter of known accuracy. It was determined that the mechanical meters did not deviate more than 5% from the EM readings. This was considered to be acceptable for the purposes of our study. Rather than precise estimation of plankton abundance, the identification of major sources of variability was the goal of our work. On the basis of readings from 144 tows taken during the three sampling days no bias was determined to exist among the three meters.

In all but one case the internal meter reading was higher than that of the external meter. This information is consistent with what has been found during MARMAP studies (Posgay and Marak, In Press), and is a result of a negative pressure drawing water around the lip as the nets fish. This has been documented with dye studies (Marak, Personal Communication). The ratios of internal to external readings were computed and found to have a standard deviation of only 0.02 and a coefficient of variability of 2.28% over 141 tows (Table 2A). It was felt that this consistency was more than acceptable for the purposes of our study. Volume filtered was computed from the distance traveled by the nets, and the cross-sectional area of each mouth opening (0.2922 m^2). Distance traveled was derived from meter readings multiplied by a constant supplied by the manufacturer. This constant was applied uniformly to all three meters following the acceptable results of the bias checks previously mentioned.

Because of the abnormal termination of two tows, their corresponding meter readings were not recorded. Consequently no volume information exists for these tows. For eight other tows, a malfunction of the inside meter resulted in loss of distance traveled information for the inside of the nets. A linear regression was used to determine the relationship between the inside and outside volumes, over all tows, and estimate the missing volumes. The slope and intercept of the regression equation are shown in Table 2B as are the regression estimates for the missing volumes. In addition, the internal meter reading for sample 184 was an outlier. This reading was rejected and the volume estimated from the outside volume using the same technique as before. During the tow corresponding to sample 243, both inside and outside readings were outliers. Because only one net of the pair contained a meter, volume filtered and two velocity for the second net had to be assumed the same as for the first. Thus, both sample 243 and 244 had to be eliminated. The meter plus its supporting rod represented 1.4% of the cross sectional area of the mouth opening. This may cause the net with the meter to filter less water due to a decrease in mouth opening or due to a disruption of flow. The net with no meter might filter more water than is estimated from the meter reading in the other net, leading to artificially high densities.

Tow velocity for each tow was computed using distance traveled by the nets, and times for both legs of the tow. As indicated in the previous section, there was negligible fishing between legs, consequently it was felt that the sum of only the times for the two legs was a reasonable estimate of tow time, ignoring time between legs. Over 141 tows, the mean tow speed was 1.6702 m/s (Table 2A). Although the absolute range of velocities was 1.2812-2.3855 m/s, most of the velocities did not deviate more than 0.25 m/s from the overall mean velocity. The coefficient of variability for tow speed was low (11.167%). The velocities were adjusted for direction; velocities from south tows were changed to negative. When separated, the absolute values of north and south tow velocities were significantly different at the level $\alpha = 0.05$. The data were collected over several tidal cycles, and tows were of an oblique nature, making a tidal-velocity relationship improbable. The wind, however, was consistently from a southerly direction, providing an explanation for higher north tow velocities.

Screening of the light meter readings showed that for the three sampling days, 0700 and 2000 hours could be used to naturally divide the days into day-night periods. This partitioning criterion will later facilitate the analysis of the response to light of the organisms collected.

As mentioned in the previous section, temperature profiles were taken hourly. Measurements were taken at the surface, at 3 meters, 5 m, 7 m, and 13 m and at the bottom (16 m) (see Appendix III). In some cases, owing to tide state and/or drift, the 13 m sample represented the bottom. Because the tows taken were of an oblique nature, thus integrating the water column, it was decided to compute a weighted mean water temperature. The mean of every pair of contiguous temperatures was assumed to be an estimate of the temperature of the corresponding water layer. These means, together with the thickness in meters of each of the water layers as weighting factors, were used to compute the weighted mean temperatures reported in the tables of Appendix III.

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The final physical data, including the estimated missing volumes and the two velocities, were stored in a disc data file labeled "TOWSPEED". This file contains 288 records of which six have 0.0 m/s tow velocities. These represent the three tows with no meter readings. A listing of this data file is included in Appendix V.

ANALYSIS OF THE BIOLOGICAL DATA

The purpose of this analysis is twofold: to identify the major sources of variability in the abundance of the organisms collected, and to devise the most suitable statistical procedures to analyze similar data collections.

No specific methodology was recognized as adequate prior to starting the study of the data. The analysis of our data was conducted in a stepwise-like manner. Initial hypotheses relative to the origin of the observed variability were successively tested. The nature of each new test was decided on the basis of the information gained from the previous one. This process continued until a logical analysis path could be identified as the most reasonable procedure to analyze the data for the purposes at hand.

Before attempting any statistical analysis, the initial raw data was transformed, reduced, and screened independently for each of the three major groups of organisms collected (i.e., fish eggs, fish larvae, and zooplankton). The raw counts of organisms were standardized by converting them into densities (i.e., number of organisms per 100 cubic meters of water filtered). In doing this, the 288 records in the initial data sets were reduced to 275. This reduction was a result of missing volume data for six samples (3 tows) as described in the preceding section, and by the loss of seven samples during collection. The resulting three new data sets, containing only the computed densities for each species, were stored in disk data files labeled as "EGGS100", "LARVA120", and "ZOOPL120". Listings of these files are included in Appendix V.

The overall and daily occurrences of each species and their average densities were computed for daytime and nighttime data separately (see Tables 6a-8d). The initial lists of species collected during the survey (See Tables 3-5) were reduced to those shown in Tables 9 and 10 on the basis of the above frequencies and average densities. The species deleted were those considered too scarce for a meaningful analysis of the biological data as a whole. The resulting new data sets, containing only the densities of the selected species, were stored in disk data files labeled as "REGGS100", "RLARV100", and "RZOOP100". These constitute the data base used in the statistical analyses described elsewhere in this section. Listings of these files are included in Appendix V.

The Log_e+1 transform of the final density data was plotted against time for each species (i.e., the 72 hour period resulting from the three sampling days). Densities from north and south tows data were plotted separately, as were the densities corresponding to each of the two bongo nets A and B (see these plots in Appendix IV).

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From examination of the frequencies and average densities for each day, it was obvious that an increasing abundance trend over the three sampling days existed. The plots of species densities against time showed that some difference existed between densities from north and south tows. Various forms of periodic response of density over time were also evident for many species. For the most abundant species, densities from A and B nets did not seem to differ greatly.

$\mathrm{Log}_e + 1$ transforms of the three final density data sets (i.e., eggs, larvae, and zooplankton) were used separately in the analyses that follow.

ANALYSIS OF VARIANCE: LINEAR MODELS

The log transformation was considered necessary to decorrelate means and variances. This also served to improve the central tendency of the data which was otherwise strongly skewed. This was particularly true for low occurrence species. Because of the large sample size (N = 275), the transformed data was assumed to be reasonably normal. Computed measures of skewness and kurtosis were found to be acceptable for most species densities.

The expected major sources of variability in our data are categorized and summarized below:

MAJOR SOURCE	EFFECT ON DENSITY DATA
- Seasonal	Changes in abundance over the three sampling days
- Time of Day	Changes in abundance over a 24 hour period due to tidal cycle and/or water temperature, and diurnal cycle
- Net Differences	Differences between the two samples from nets A and B
- Avoidance	Changes in abundance over a range of tow velocities. Individual species response may be light dependent also.

Since it was previously found (see Analysis of Physical Data) that the mean tow velocities from north and south tows were significantly different, it was decided that the first test to perform was one comparing overall mean densities from north and south tows. To improve the sensitivity of this test the seasonal trend observed during the previous screening of the data was removed. Each of the three groups of data was split into two categories (i.e., north and south tows) and detrended over days by a second order polynomial regression. The fit was highly significant, and better than with a simple linear regression. Plots of the data for larvae-species No. 1 (anchovy) against time (i.e., the 72 hour period of the three sampling days) are shown

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in Figures 4 and 5, before and after detrending. Figure 5 is a plot of the residuals or deviations from the polynomial regression line, thus representing the density data after the removal of the "days" effect. This plot shows a clear harmonic response to time, with a dominant period of approximately 12 hours.

The residuals described above were used in a simple analysis of variance to test for the effect of tow direction alone. It was found that the difference between north and south tows was not significant for any species ($P > .68$ in the case of anchovy larvae). A second test for the same response over all species (multivariate model) was also not significant ($P > .606$ for all larvae species). Similar results were found for eggs and zooplankton. Although these results may imply no overall avoidance response to changing tow velocities, it should be recognized that the velocity range was too narrow to validate any test of this hypothesis. Nevertheless, in terms of this study, the results of these tests proved that data collected in north and south tows could be used as replicates for other analyses.

In the next step, the same free of "days" effect data were used in a correlation analysis to determine whether or not the data could still be correlated linearly with time (hours of the day). The correlation coefficients were less than 0.10 for all species, indicating that the strongly harmonic nature of the response to time could no be explained by means of a linear model. Thus, no analysis of variance based on linear models would show a significant time response.

It was felt that if the data were classified according to the computed tidal factor for each sample (see Data Collection: Materials and Methods), then samples collected at high tide could be compared to those collected at low tide. From a simple inspection, it was obvious that large differences between the means of these two groups existed for most species of larvae and zooplankton. Thus, this procedure could be used to test for tidal response alone. A similar procedure could be used to linearize a possible harmonic response to light (diurnal cycle) expected on the basis of biological considerations. To test for this response, the data could be grouped into day and night samples as was done during the data screening. However, since both harmonic responses are inherently out of phase and have different periods, it was evident that the data could never be grouped in such a way as to linearize the responses to both the tidal and diurnal cycles at the same time. Because both responses occurred simultaneously, it was concluded that linear models of analysis of variance (ANOVA) alone were inadequate to analyze the temporal variability of our data.

If the tidal cycle was linearized, the variability due to the diurnal cycle would appear confounded with the "within" or error term. In the case of fish eggs, found to exhibit a strong day-night response (see Tables 6a-6d and plots in Appendix IV) the inflated error term would decrease the sensitivity of the test for any other effect included in the ANOVA model. In the case of larvae and zooplankton, screening of the data showed that both tidal and diurnal responses were present, but provided no evidence

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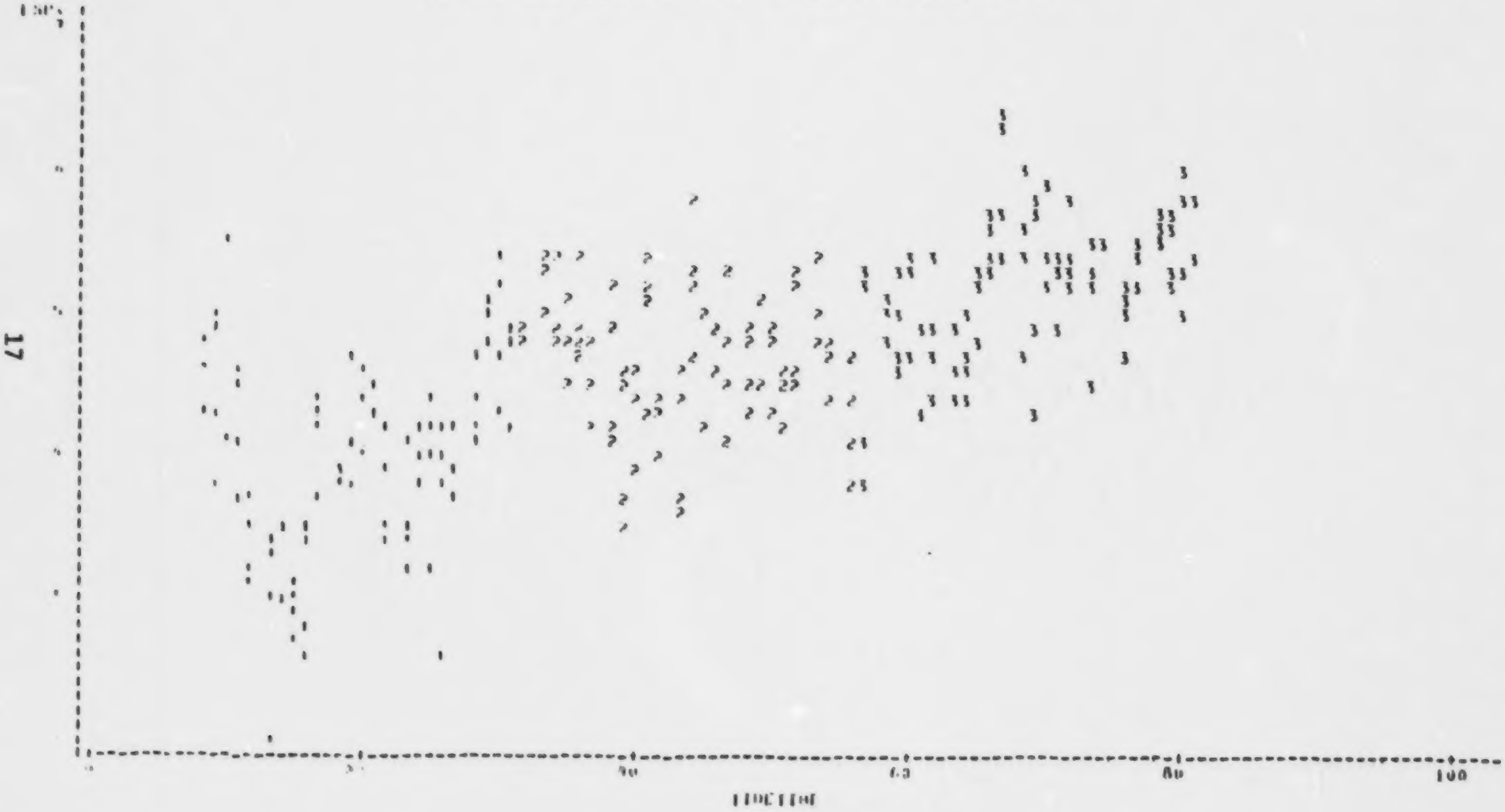

Figure 4

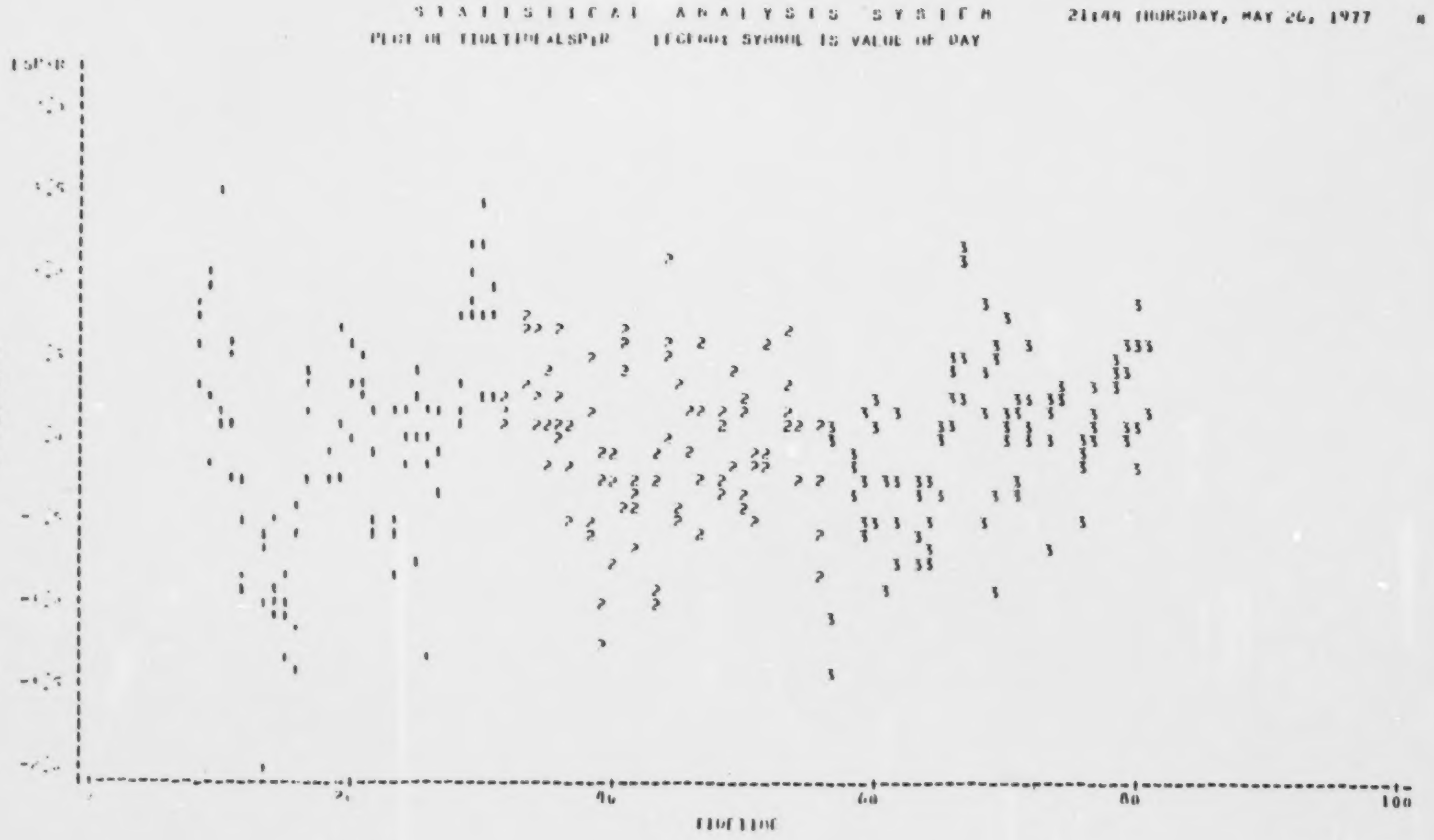
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Figure 5

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as to which was the predominant one. On the other hand, without any sound basis for expecting a tidal response in the abundance of eggs, the linearization of the diurnal effect, and its inclusion in the ANOVA model, most likely would keep the error term sufficiently low to test for the other effects. Since it was not apparent which would be the best choice for ANOVA tests with larvae and zooplankton data, on the grounds of consistency it was decided to include only the day-night time effect in the multivariate ANOVA model used for the three groups of data in the next step of the analysis. Without considering the tidal cycle or the avoidance response to tow velocity, which was found not to be significant, the remaining sources of variability to test were: seasonal (days effect), diurnal (day-night effect), and nets. By classifying our final data set according to these main effects, the 275 valid observations were partitioned as follows:

$$N = (n_S) \times (n_D) \times (n_N) \times (r) - m = 275$$

where n_S = 3 levels of seasonal effect (3 days)

n_D = 2 levels of diurnal effect (day-night)

n_N = 2 levels of nets effect (2 nets)

r = 24 replicates (2 x 12) from 2 tow directions and 12 hours within each of the 2 levels of the diurnal effect

m = 13 missing samples

Due to the extremely uniform environmental conditions encountered over the three sampling days the SD (seasonal-diurnal) interaction was not considered of interest. The second order interaction, SND (seasonal-diurnal-nets) was unrealistic in terms of interpretation and was also dropped from the general ANOVA linear model. Thus the model reduced to:

$$Y_{ijkl} = \mu + S_i + D_j + N_k + SN_{ik} + DN_{jk} + \varepsilon_{ijkl}$$

thus pooling the missing terms SD_{ij} and SND_{ijk} with the random error term, ε_{ijkl}. According to the above model, the partitioning of the available degrees of freedom (N - 1 = 274) for testing resulted in the univariate ANOVA table shown in Table 11. The high sensitivity of this test was guaranteed by the large number of d.f. available for the error term (w = 267). The results of these tests are shown in Tables 11, 12, and 13 for eggs, larvae, and zooplankton respectively. These tables also include the results of the three multivariate ANOVA's conducted to test the hypothesis of no overall species response to the same main effects and interactions considered for the single species responses. All these analyses are discussed in the following section.

The statistical analyses performed so far were done using the standard programs available in the 1976 version of the Statistical Analysis System (SAS) computer package.

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Spectral Analysis and Periodic Regression

As an alternative to linearizing the periodic responses of the organisms to diurnal and tidal cycles, their variance components can be removed prior to testing for those responses known to be linearly correlated with time. This approach was fully investigated and found to be the most adequate for our data.

The $\log_e + 1$ transformed density data for larvae species 1 (anchovy) was used to test the techniques. Figure 6 shows the periodogram obtained as the result of a spectral analysis conducted on the mentioned data which had been detrended from the "days" effect (i.e., the residuals of the second order polynomial regression shown in Fig. 5). This periodogram shows the dominant periods observed in the data and their relative importance on an arbitrary scale from 0 to 10 (the Y axis). The X axis is the time scale spanning the 72 hours (i.e., the three sampling days). Although this analysis, performed using a SAS algorithm, did not provide a test for the significance of the periodic responses, it did show that three dominant periods of approximately 12, 24, and 36 hours existed. This result provided the necessary base to proceed with the next step of the analysis.

Sameoto (1975) used a harmonic regression analysis based on the mathematical model and technique described by Bliss (1958). Our approach differed from Sameoto's in that here we were not concerned with the analysis of variance itself, but with the simultaneous removal of two known periodic responses from our data. The periodic regression technique due to Bliss is used in the context of a non-linear covariance analysis, as the procedure to generate residuals from the fitted harmonic functions. These residuals, free of periodic components, are then used in a subsequent regular ANOVA test to detect any other significant response under investigation. A major advantage to this approach is that it is possible to test for any response linearly correlated with time, within the frame of a multivariate ANOVA model (overall response of various species), which has higher sensitivity than any conventional univariate test.

The periodic regression model is basically a curvilinear regression in which the orthogonal polynomial powers of X, of the familiar polynomial regression, are replaced by sinusoidal terms. The simplest form of this periodic regression model is:

$$\overline{Y} = a_o + [a_1\cos(ct) + b_1\sin(ct)]$$

where: a_o = the linear component or mean of the response $\overline{Y}$ over the entire period analyzed

$c = 2\pi/k$, converts the discrete time units, $t = 0,1,2,\ldots,k-1.$ on the X axis into radians

t = the independent variable X, represents each point in time

a_1 and b_1 = the fitted parameters which define both the amplitude and the phase angle, θ, of the sinusoidal curve

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SPECTRAL ANALYSIS of the residuals from the Log_e+1 density data for larvae species 1 after removing the "days" effect. Periodogram showing the dominant periods observed.

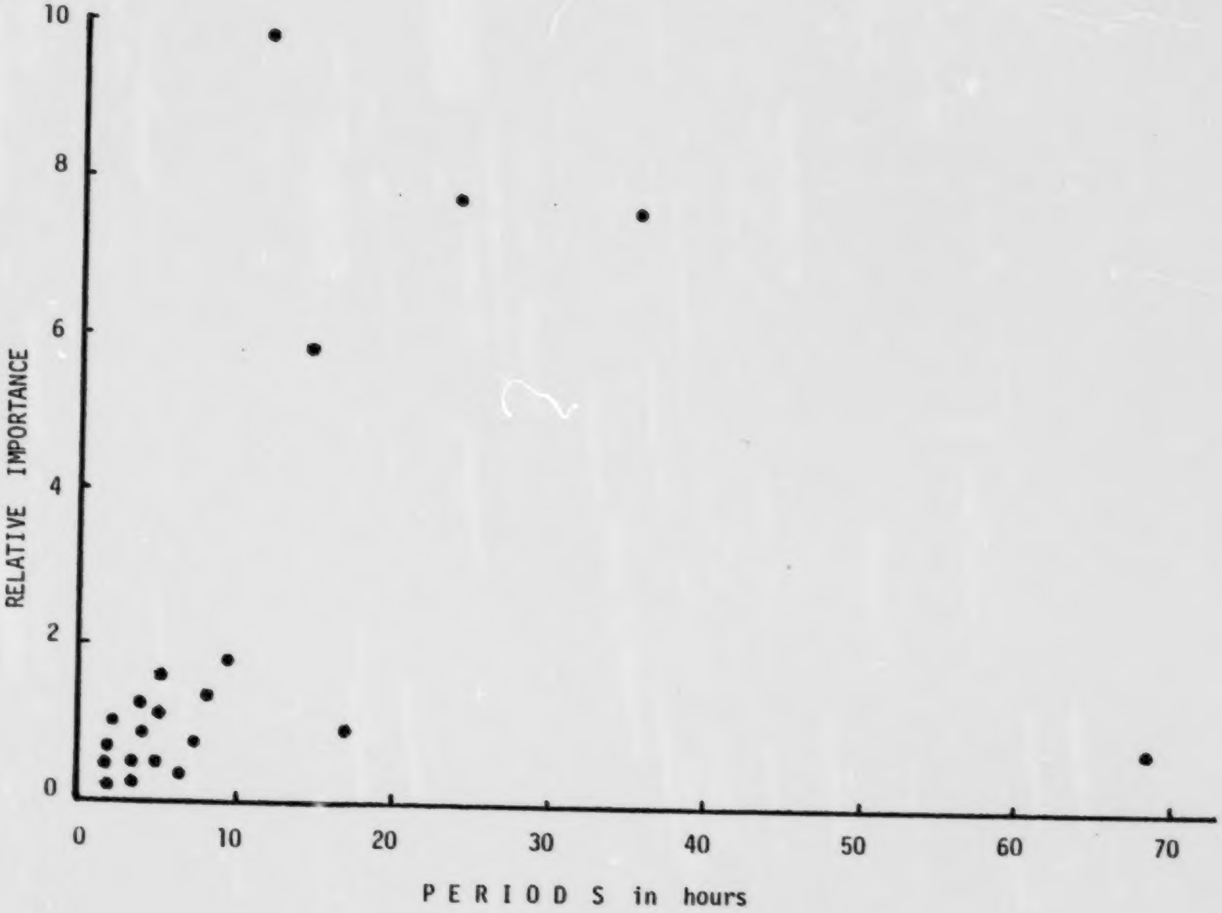

Fig. 6

$A = \sqrt{a_1^2 + b_1^2}$ is the semi-amplitude (one-half of the range from the maximum to the minimum response

$\tan = b_1/a_1$ is the slope of the curve

The above equation will fit data which when plotted against time, show only a single cycle over the entire time span analyzed. If this span is equal to 24 hours, then t = 0,1,2,...,k-1 for k = 24, assuming that there are observations available at one hour intervals over the 24 hours. By expansion of the Fourier series, it is possible to add any number of terms to Eq. (1) in order to fit as many different periodic responses as may be presented in the data. Eq. (1) then takes the form:

$$\overline{Y} = a_o + [a_1\cos(ct) + b_1\sin(ct)] + [a_2\cos(2ct) + b_2\sin(2\,ct)] + \dots\dots + [a_n\cos(nct) + b_n\sin(nct)] \qquad (2)$$

Eq. (1) is termed as the "first harmonic" (one-cycle curve), while Eq. (2) represents curves of higher order. Second, third, ...,n^th^ harmonic terms would be necessary to fit curves with 2,3,...,n cycles over the time span analyzed.

Since our detrended data (Fig. 5) showed six cycles over a 72 hour period, or two cycles per day, they were broken down into three sets of data, one for each day, with observations for each of the 24 hours. In this manner, data from each day were treated as replicates. An equation with "first and second harmonic" terms (n = 2 in Eq. 2) was fitted to these data assuming that two different responses with 12 and 24 hour periods respectively (i.e., tidal and diurnal cycles) were present. The result of this regression is shown in Figure 7 where deviations of each replicate (points 1, 2, or 3) from the periodic curve are plotted against the 24 hour time span analyzed.

The algorithm utilized was program 04R, available in the "Biomedical Computer Programs" (BMD) computer package. This algorithm fits the equation in a stepwise manner. First, the parameter a_o is computed and then the "first harmonic" term of the equation is fitted by estimating the parameters a_1 and b_1 using the least squares criterion. In a second step, the "second harmonic" term of the equation is fitted by estimating the parameters a_2 and b_2 while retaining the values assigned to the parameters a_o, a_1, and b_1 in the previous step. An analysis of variance is performed after each step providing the sums of squares needed to compute the percents of the total variance explained by the first and second harmonic terms respectively. The replicates' effect is also tested, thus it is possible to determine whether or not the responses were significantly different for each replicate ("days" in our case). Table 15 summarizes this information for the trial test performed. The residuals or deviations from this regression are the data detrended per the "days" effect and free of diurnal and tidal response components. These residuals are thus suitable for a highly sensitive analysis of the remaining effects by means of regular ANOVA tests.

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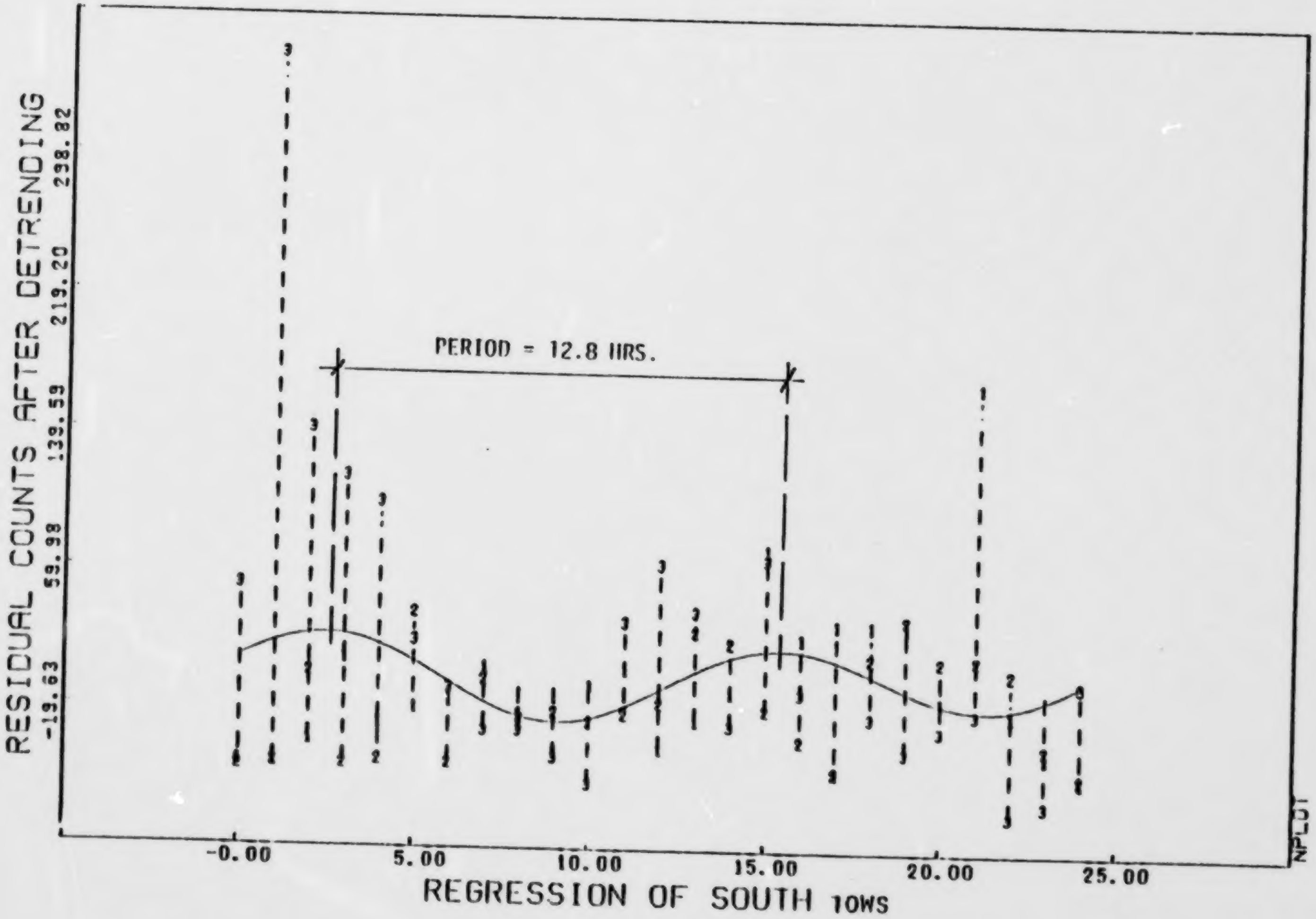

DATA FOR ANCHOA SP. LARVAE

Figure 7

In addition, the interpretation and comparison of the parameters fitted may provide meaningful biological information as to how different species respond to the diurnal and tidal cycles.

Final Remarks

The described procedure to fit periodic functions of time to plankton data, may be also used to obtain an unbiased estimate of the absolute mean abundance of a species over a given time span. The fitted periodic function of the type of Eq. (2) can be easily integrated between the two finite limits $t = 0$ and $t = k-1$. The result of this integration is the area defined by the periodic curve above and below the mean value a_o, when that parameter is equated to zero in Eq. (2). This area, divided by the number of time units, k, would yield the linearized component of the mean periodic response to be added to a_o. This mean, of course, would not include the "days" effect previously removed from the data.

Finally, a sampling strategy can be devised in order to take full advantage of the predictive capabilities of the periodic regression equation. Assuming that a given species responds consistently to diurnal and tidal cycles, it seems reasonable to expect, that once that response has been characterized by fitting a periodic function to a complete set of data collected hourly over a 24 hour period, it would be possible to assess temporal changes in abundance by sampling only at high and low tide and at noon and midnight. These data could be used to recompute the parameters of the previously fitted periodic function and to determine whether or not the new mean estimates were significantly different from the previous ones.

In the case of a large sampling area with several stations, it would be impractical to sample simultaneously in all stations at the same time (i.e., at high and low tide and at noon and midnight). However, again using a previously fitted function to data collected at a "control" station over a 24 hour period, it would be possible to adjust for small differences in the time scale and to predict what response would have been measured at the fixed points in time: high tide, low tide, noon, and midnight. Once the functions have been fitted, comparisons among stations would be possible.

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SECTION V

DISCUSSION

Among the sources of variability analyzed, an avoidance response to changes in tow velocity could not be detected. From the plot of velocities against time (Fig. 8), it can be seen that not only was there a distinct separation of the north and south tows, but there was also a periodic fluctuation in both the north and south tow velocities. The north and south differences were due to the prevailing southerly wind which produced higher north tow velocities, in spite of constant engine RPM's. The cyclic oscillation in the velocity had a tidal period. We feel that this periodicity results from the oblique nature of the tows integrating a water column which is vertically stratified with respect to its tidal undercurrents. The periodicity depicted in Figure 8 might be explained by the time lag in current changes between contiguous water layers, which is typical of estuaries.

While the differences between north and south tow velocities were significant, the differences between the mean species densities for north and south tows were not. The range in velocities was small. If this range had been greater, then some effect might have been observed. In fact, high winds and/or extreme tides may produce a large enough range in velocity to make visible the avoidance response, thus affecting densities. This should be investigated.

The other sources of variability were analyzed by means of the ANOVA test described in the preceding section. The seasonal effect was found highly significant for the majority of species; the diurnal effect had various degrees of significance in the three groups of organisms (i.e., eggs, larvae, and zooplankton); evidence of the presence of a tidal response was found for larvae and zooplankton; and nets effect was found significant for eggs and a few larvae species (see Tables 12-14).

The high significance of the seasonal response (days effect) was expected since the sampling period coincided with the spawning of many fish species. The significance of the nets effect requires a more elaborate explanation, taking into account the facts that the tidal effect was not included in the ANOVA linear model, and that only one net had a flow meter inside.

Differences between the fishing rate of the two nets of a pair of Bongo nets is contrary to what has been reported before (Sameoto, 1975; Posgay and Marak, in press). However, while in other studies each net had a flow meter

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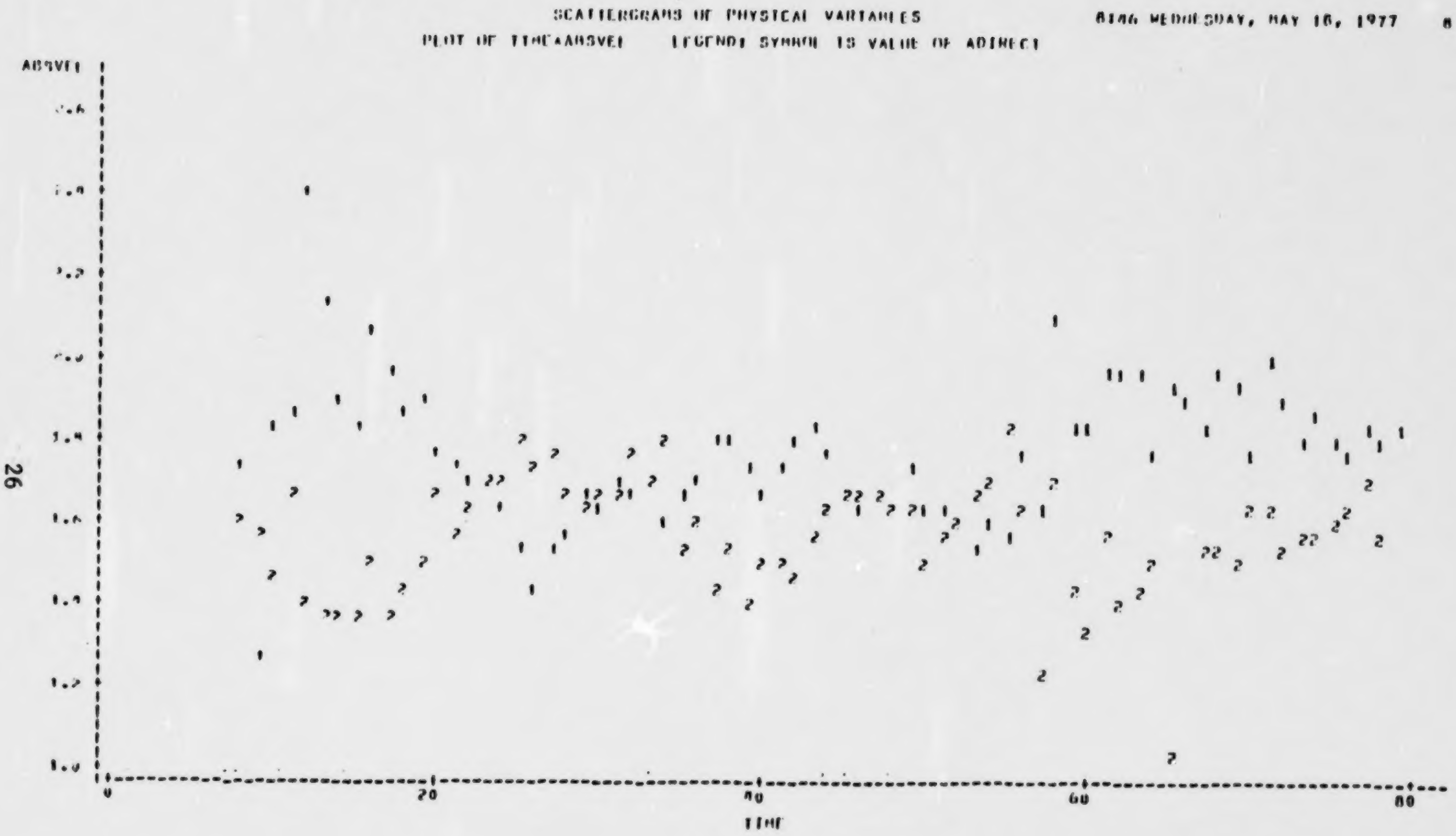
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TIME

Figure 8

in the mouth, in this study only one net had a meter inside. A second meter was external to the other net (see Fig. 2). This was intentionally done in order to test for the significance of the bias introduced by the reduction of the mouth area and/or disruption of flow by the meter. Posgay and Marak (in press) have demonstrated that meter placement does not affect the reliability of volume estimates unless it is placed adjacent to the wall of the frame. For this reason, in our study, the meter was placed in the geometric center of the net.

Assuming identical nets, and no meter effect, differences in fishing rates could be attributed to patchiness, if and only if, these differences occurred because either Net A or Net B was fishing more than the other in a random manner. Testing for this random bias can be accomplished by means of a 2 x 2 contingency table chi-square test of independence. The discrete data would be the raw counts of each species over all tows for each net, classified as "high" or "low", according to whether Net A or Net B had the larger count. The two nets would be the first dimension of the contingency table, and the two categories (high and low) would be the second dimension. In the case of A meter in each of two identical nets, this test would answer the question of whether there was any bias between the two meters. In this study, with only a single meter, always in the same net, the above test could answer the question of whether or not the meter had any effect on fishing rate. However, the screening of our data showed that Net A (with no meter) had consistently higher counts for all species. Because of this already well defined bias, the net effect was included in the general ANOVA linear model as one of the three main effects tested for.

The result of this test was a highly significant overall species nets effect for eggs, but not for either larvae or zooplankton. This apparent inconsistency can be explained by the higher sensitivity of the test for eggs. This group in general, exhibited the strongest response to the diurnal cycle, which had been linearized and included in the ANOVA model as a main effect. In addition, eggs are the only group from which no avoidance response can be expected. Thus, the variability due to this untested response was confounded with the true random variability only in the cases of larvae and zooplankton. For all three groups the variability due to tidal response was also confounded with the random variability. Consequently, the tidal cycle response was the only possible source of non-random variance in the "within" or error sum of squares for eggs.

Some evidence supporting the above explanation can be found when looking at the results of the univariate ANOVA tests for individual species within each of the three groups. Table 16 shows the total percent variance explained by the model for selected species of each group, broken down into its two major components: seasonal and diurnal effects. The total percent variance explained by the model, the mean density, and the coefficient of variability (C.V.) were used as criteria to select the species included in Table 16. In general, species with low occurrence (many zero density data points) had a large C.V., together with a small mean, and the model was unable to explain more than 10% of the total variance. These species were not included in the table because the unreliable data would invalidate any interpretation of the test. According to these criteria, only for egg species 1, 2, 3, 4, 5, and 7 were the tests considered valid (see Table 11). For species 3 and 5, the percent of the variance explained by the test was low. The only possible interpretation is that the model does not account for the major sources of variability for these two species. Perhaps a strong tidal response of the spawners exists. For the other egg species in Table 16, the nets effect was significant and for all of them the diurnal variance component was larger than the seasonal one. In the larvae group, the tests for species 1, 2, 3, 4, and 7 were accepted according to the same criteria used for the eggs group. Table 16 shows the only larvae species (1, 2, and 7) that had a significant nets effect. These three species were the only ones for which the model explained more than 40% of the total variance; instead of diurnal, in this case the seasonal effect was the most important variance component. It is obvious that, as for eggs, when the total percent of variance explained was low, the nets effect could not be detected as significant. In the case of larvae species 3 and 4 the seasonal variance component was not high enough to permit the nets effect to show in absence of the tidal variance component which was missing from the model. In the zooplankton group, the tests for species 1, 2, 3, 4, 5, 9, 10, 12, and 14 were accepted with the same criteria as before. Table 16 shows that only for species 9, 12, and 14 was the variance explained more than 40% of the total. However, these three species did not show a significant response to the nets effect. This suggests that their behavior (avoidance response) was different than that of larvae, and somehow decreased the tendency of Net A to fish more than Net B. In all the remaining zooplankton species, no nets response could be detected because of the low sensitivity of the test in the absence of either strong seasonal or diurnal responses.

Summarizing the discussion of the ANOVA test, it can be concluded that unless the organisms' nonlinear responses to diurnal and tidal cycle are removed, they can impair the ability of a linear model ANOVA to detect other linear responses. The suspected different avoidance response of the various types of organisms, which has so far gone untested, may play an important role in modifying other effects by introducing a non-random source of variance in the error term when testing over all species. In other words, only species with similar avoidance responses should be considered together for a multivariate test. The removal of the organisms' response to tidal and diurnal cycles can be accomplished by using harmonic regressions in the manner discussed in the preceding section. The residuals from these regressions can then be used to test for the significance of the linear variance components by means of a multivariate analysis of variance. This two-step analytical procedure is in fact a "non-linear covariance analysis" specifically designed to remove from the error term significant harmonic variance components usually present, and seldom taken into account when analyzing estuarine plankton data. In addition, the application of the above nonlinear covariance analysis technique leads to an optimal sampling strategy for monitoring programs in estuarine environments.

In our study, the only measurable physical difference between the nets was a reduction of 1.4% in the mouth area of Net B due to the inside flow meter. This small difference was apparently enough to create a significant net effect for eggs and larvae, whenever the sensitivity of the test was greater than 40% (i.e., ability of the model to explain at least 40% of the total variance). This points out the need for placing flow meters inside both nets. This, together with an adequate standardization of the frames and nets, should insure the absence of net bias.

In order to reduce costs of processing samples (i.e., identification and counting) it might be valuable to attempt to establish a count/biomass relationship for each species. This could be done for each batch of samples, corresponding to a day, a week, etc. Unfortunately, however, a problem arises due to plankton volume loss with time of preservation (Ahlstrom and Thrailkill, 1962). Several alternatives provide solutions to the problem. The samples may be processed for volume (1) immediately upon collection, (2) after a "standard" period of time, or (3) following a predetermined stabilization period. The latter would appear to optimize the quality of the data while being most practical logistically.

Table 1. 1976 Narragansett Bay - E.P.A. ichthyoplankton sampling project. Tidal cycles in the sampling days.

	DAY 1 (28-29 June)		DAY 2 (1-2 July)		DAY 3 (7-8 July)	
Tides	Time	Water Level	Time	Water Level	Time	Water Level
Low	-	-	0337	-0.091	-	-
High	0816	1.189	1031	1.250	0341	1.158
Low	1332	-0.030	1552	-0.030	0913	-0.030
High	2031	1.402	2248	1.311	1615	1.463
Low	0214	-0.091	0411	-0.091	2232	0.030
High	0900	1.219	1123	1.280	0441	1.189
Low	-	-	-	-	1012	-0.061

Times corrected for Prudence Island (Sandy Pt.)

Tides referred to mean water level in the Bay (in meters)

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Table 2a. Statistics computed from available data on volume ratios and towing velocities.

	Inside/Outside Volumes Ratio	Towing Velocities
No. of Observations	141	141
Mean	1.1524	1.6702 m/sec
Std. Deviation	0.0263	0.1865
Coeff. of Variability	2.283%	11.167%

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Table 2b. Estimation of missing inside volumes by regression on outside volumes: (volumes expressed in cubic meters)

Number of Observations Used	Intercept	Slope
132	19.843002	0.958847

Sample	REGRESSION ESTIMATES Inside Volume	Outside Volume
195	115.929	100.210
209	120.865	105.358
213	113.432	97.606
235	121.191	105.698
295	121.524	106.045
307	120.146	104.608
311	128.134	112.939
349	114.625	98.850
185	111.513	95.604

Table 3. List of species and species groups whose eggs were found during the June-July 1976 survey.

1.	*Anchoa hepsetus*	striped anchovy
2.	*A. mitchilli*	bay anchovy
3.	*Brevoortia tyrannus*	Atlantic menhaden
4.	*Enchelyopus*-*Urophycis*-*Peprilus*	rockling-hake-butterfish
5.	*Etropus microstomus*	smallmouth flounder
6.	Labridae	wrasses
7.	Labridae-*Limanda*	wrasses-yellowtail flounder
8.	*Merluccius bilinearis* III	silver hake
9.	*Merluccius*-*Stenotomus*-*Cynoscion*	silver hake-scup-weakfish
10.	*Morone* sp.	white perch (?)
11.	*Paralichthys*-*Scophthalmus*	summer flounder-fluke
12.	*Peprilus* sp.	butterfish (?)
13.	*Prionotus* sp.	searobin
14.	*Stenotomus*-*Cynoscion* III	scup-weakfish
15.	*Trinectes maculatus*	hogchoker

Table 4 . List of species whose larvae were found during the June-July 1976 survey.

1.	*Anchoa* sp.	anchovy
2.	Clupeidae	
3.	*Cynoscion regalis*	weakfish
4.	*Enchelyopus cimbrius*	fourbeard rockling
5.	*Gobiosoma ginsburgi*	seaboard goby
6.	*Menidia* sp.	silverside
7.	*Merluccius bilinearis*	silver hake
8.	*Paralichthys oblongus*	fourspot flounder
9.	*Peprilus triacanthus*	butterfish
10.	*Prionotus* sp.	searobin
11.	*Pseudopleuronectes americanus*	winter flounder
12.	*Scophthalmus aquosus*	windowpane
13.	*Sphoeroides maculatus*	Northern puffer
14.	*Stenotomus chyrsops*	scup
15.	*Syngnathus fuscus*	Northern pipefish
16.	*Tautoga onitis*	tautog
17.	*Tautogolabrus adspersus*	cunner
18.	*Trinectes maculatus*	hogchoker
19.	Biomass ml/1000 m^3	

Table 5. List of species of zooplankton found during June-July 1976 survey.

1. *Acartia clausi*
2. *A. tonsa*
3. *A.* spp.
4. Barnacle cypris
5. *Calanus* sp.
6. *Centropages hamatus*
7. *C. typicus*
8. *C.* sp.
9. Crab megalopa
10. Crab zoea
11. Cumacea
12. *Ensis directus*
13. *Eurytemora* sp.
14. *Evadne* sp.
15. Gastropoda (larvae)
16. Harpacticoida
17. *Labidocera aestiva*
18. Mysidacea larvae (juv)
19. Nauplii
20. *Oithona similis*
21. *Oithona* sp.
22. Paguroidae (juv)
23. *Penilia avirostris*
24. *Podon* spp.
25. Polychaeta larvae
26. *Pseudocalanus minutus*
27. *Pseudodiaptomus coronatus*
28. Pycnogonida
29. *Sagitta* spp.
30. *Stomotopoda* larvae
31. *Temora longicornis*
32. *Tortanus discaudatus*
33. Unknown Calanoida
34. " Cephalocardia
35. " Cephalopoda
36. " Copepoda (adult)
37. " medusoid

Table 6a. EGGS

Species No.*	Sum of Densities Over all Samples	No. of Occurrences	Average Density of all Occurrences
1	1709851.00	275	6217.63
2	84270.18	274	307.55
3	35169.82	275	127.89
4	33027.06	271	121.87
5	10796.91	273	39.54
6	1016.31	156	6.51
7	6924.35	269	25.74
8	24107.47	260	92.72
9	2765.43	238	11.61
10	158.31	98	1.61
11	776.38	169	4.59
12	55.72	34	1.63
13	289.96	108	2.68
14	586.70	166	3.53
15	21.68	17	1.27

* See Table 3 for species number identification

EGGS

Table 6b. Breakdown of species occurrence during sampling day 1.

Species No.	Day Hrs. (8 AM-7 PM)		Night Hrs. (8 PM-7 AM)		Total Freqs.
	Freqs.	Avg. Density (counts/100 m^3)	Freqs.	Avg. Density	
1	47	1956.870	47	5125.398	94
2	46	164.7180	47	361.8145	93
3	47	60.37738	47	71.81973	94
4	45	19.57443	47	102.7265	92
5	46	34.79976	46	37.70815	92
6	26	1.091431	29	1.548733	55
7	45	10.99245	47	16.95074	92
8	42	9.921258	47	38.68654	89
9	40	4.830465	41	10.47207	81
10	12	1.115868	17	1.301718	29
11	28	2.358469	35	3.849470	63
12	20	2.156716	10	0.9215821	30
13	12	1.243497	15	1.185389	27
14	16	1.353317	19	2.280848	35
15	0	0.0	0	0.0	0
Average	31.47	162.24	32.93	412.62	

EGGS .

Table 6c. Breakdown of species occurrence during sampling day 2.

Species No.	Day Hrs. (8 AM-7 PM) Freqs.	Day Hrs. (8 AM-7 PM) Avg. Density*	Night Hrs. (8 PM-7 AM) Freqs.	Night Hrs. (8 PM-7 AM) Avg. Density	Total Freqs.
1	48	3538.044	43	6155.754	91
2	48	109.3447	43	415.0945	91
3	48	110.4978	43	145.3604	91
4	47	24.52722	42	245.3816	89
5	48	41.36298	43	39.52341	91
6	20	1.589128	33	2.992507	53
7	47	13.29972	41	39.54800	88
8	42	12.55233	43	117.1143	85
9	39	21.30357	33	15.40774	72
10	4	0.8854222	13	1.578958	17
11	19	1.400954	32	5.888632	51
12	3	0.8576943	1	0.8036002	4
13	11	0.9299195	10	1.577868	21
14	16	1.073378	27	3.736056	43
15	0	0.0	3	0.8073962	3
Average	29.33	276.97	30.00	479.37	

* counts/100 m^3

EGGS

Table 6d. Breakdown of species occurrence during sampling day 3.

Species No.	Day Hrs. (8 AM-7 PM) Freqs.	Day Hrs. (8 AM-7 PM) Avg. Density *	Night Hrs. (8 PM-7 AM) Freqs.	Night Hrs. (8 PM-7 AM) Avg. Density	Total Freqs.
1	44	5783.027	46	14957.15	90
2	44	245.6704	46	560.4744	90
3	44	191.2919	46	195.3396	90
4	44	51.17314	46	295.8235	90
5	44	33.64363	46	49.92509	90
6	9	1.723384	39	20.43547	48
7	44	11.08889	45	64.41351	89
8	41	20.97916	45	343.3196	86
9	41	7.887040	44	10.91383	85
10	22	1.968772	30	1.847018	52
11	19	1.412462	36	9.270203	55
12	0	0.0	0	0.0	0
13	25	1.767668	35	5.344597	60
14	42	4.236056	46	4.907898	88
15	3	0.8687782	11	1.513807	14
Average	31.07	454.05	37.40	1180.05	

* counts/100 m^3

Table 7a. Larvae

Species No.*	Sum of Densities Over All Samples	Number of Occurrences	Average Density of All Occurrences
1	34743.03125	275	126.33829
2	1443.253174	247	5.8431301
3	226.8614197	166	1.3666344
4	244.7612152	153	1.5997458
5	88.99351501	82	1.0852861
6	63.81898499	54	1.1818323
7	385.2661133	120	3.2105503
8	104.3825226	82	1.2729568
9	110.2959290	48	2.2978315
10	140.7165833	110	1.2792416
11	21.19810486	22	0.96355021
12	26.33201599	28	0.94042909
13	192.5999908	103	1.8699026
14	4.677545547	6	0.77959090
15	0.9076716304	1	0.90767163
16	5.154928207	6	0.85915470
17	3.267806053	4	0.81695151
18	0.8061590195	1	0.80615902
**	22275.05859	275	81.000198

* See Table 4 for species number identification

** Biomass (eggs + larvae + zooplankton; m.l./1000 m^3)

LARVAE

Table 7b. Breakdown of species occurrence during sampling day 1.

Species No.	Day Hrs. (8 AM-7 PM)		Night Hrs. (8 PM-7 AM)		Total Freqs.
	Freqs.	Avg. Density[a]	Freqs.	Avg. Density	
1	47	56.34244	47	76.74150	94
2	35	2.918933	38	2.676608	73
3	21	1.140170	24	1.223938	45
4	23	1.455474	22	1.077101	45
5	16	1.165565	15	1.060946	31
6	7	1.100590	6	0.8228741	13
7	1	0.8339031	6	0.9572803	7
8	13	1.019056	8	1.005357	21
9	9	1.886833	2	1.217845	11
10	7	1.001159	10	1.051827	17
11	3	0.8690701	1	0.8142726	4
12	2	0.8621840	0	0.0	2
13	0	0.0	1	0.8490046	1
14	0	0.0	4	0.7670145	4
15	0	0.0	0	0.0	0
16	0	0.0	0	0.0	0
17	0	0.0	0	0.0	0
18	0	0.0	0	0.0	0
19[b]	47	31.01616	47	100.2616	94
Average*	18.22	8.66	10.22	10.22	5.01

* Excluding biomass   a = counts/100 m^3 b = ml/1000 m^3

LARVAE

Table 7c. Breakdown of species occurrence during sampling day 2.

Species No.	Day Hrs. (8 AM-7 PM) Freqs.	Day Hrs. (8 AM-7 PM) Avg. Density[a]	Night Hrs. (8 PM-7 AM) Freqs.	Night Hrs. (8 PM-7 AM) Avg. Density	Total Freqs.
1	48	115.5362	43	118.4179	91
2	41	3.099994	43	7.305891	84
3	25	1.093993	27	1.163815	52
4	22	1.522818	15	1.215415	37
5	18	1.134063	17	1.019356	35
6	3	0.8865223	13	1.144308	16
7	10	0.8521259	19	1.313385	29
8	15	1.188581	17	1.619613	32
9	9	1.898643	4	2.439443	13
10	25	1.550117	20	1.068772	45
11	0	0.0	7	0.8191689	7
12	3	1.138874	6	0.9505473	9
13	9	1.048450	15	1.370743	24
14	0	0.0	0	0.0	0
15	0	0.0	0	0.0	0
16	3	0.8704055	1	0.8381106	4
17	0	0.0	0	0.0	0
18	0	0.0	0	0.0	0
19[b]	48	37.07100	43	146.7770	91
Average*	12.83	7.32	13.72	7.82	

* Excluding biomass a = counts/100 m^3 b = ml/1000 m^3

LARVAE

Table 7d. Breakdown of species occurrence during sampling day 3.

Species No.	Day Hrs. (8 AM-7 PM) Freqs.	Day Hrs. (8 AM-7 PM) Avg. Density[a]	Night Hrs. (8 PM-7 AM) Freqs.	Night Hrs. (8 PM-7 AM) Avg. Density	Total Freqs.
1	44	184.1997	46	211.8655	90
2	44	5.518880	46	12.07202	90
3	30	1.361813	39	1.895296	69
4	34	1.875853	37	1.948035	71
5	6	0.8605704	10	1.152510	16
6	5	0.8981781	20	1.457467	25
7	43	4.093389	41	4.126818	84
8	18	1.539658	11	0.9105759	29
9	15	3.310065	9	1.598043	24
10	28	1.361393	20	1.247159	48
11	3	0.8625298	8	1.181862	11
12	7	0.8797067	10	0.9329861	17
13	37	1.743919	41	2.371437	78
14	0	0.0	2	0.8047438	2
15	1	0.9076716	0	0.0	1
16	1	0.8959128	1	0.8096904	2
17	1	0.8355685	3	0.8107462	4
18	0	0.0	1	0.8061590	1
19[b]	44	51.69397	46	124.7810	90
Average*	17.61	11.73	19.17	13.67	

* Excluding biomass a = counts/100 m^3 b = ml/1000 m^3

Table 8a. ZOOPLANKTON

Species No.*	Sum of Densities Over all Samples	No. of Occurrences	Average Density of all Occurrences
1	5442.37	183	29.74
2	1187898.00	275	4319.63
3	49558.06	270	183.55
4	229307.81	273	839.96
5	152300.38	274	555.84
6	4434.26	118	37.58
7	5997.50	162	37.02
8	654.50	38	17.22
9	30918.74	202	153.06
10	12298.31	210	58.57
11	2399.19	114	21.05
12	5376.36	100	53.76
13	5841.46	178	32.82
14	113.95	8	14.24
15	9349.66	174	53.73
16	166.93	13	12.84
17	628.58	27	23.28
18	5838.88	29	201.34
19	67.53	6	11.25
20	102.89	10	10.29
21	2489.62	39	63.84
22	28.26	3	9.42
23	276.53	17	16.27
24	97.19	5	19.44
25	94.52	5	18.90
26	672.53	31	21.69
27	41.53	4	10.38
28	843.65	42	20.09
29	107.72	6	17.95
30	4207.75	59	71.32
31	475.63	17	27.98
32	6.49	1	6.49
33	10.12	1	10.12
34	217.88	4	54.47
35	6.24	1	6.24
36	11.59	1	11.59
37	25.99	1	25.99

* See Table for species number identification

Table 3b. Breakdown of species occurrence during sampling day 1.

Species No.	Day Hrs. (8 AM-7 PM)		Night Hrs. (8 PM-7 AM)		Total Freqs.
	Freqs.	Avg. Density *	Freqs.	Avg. Density	
1	42	37.16972	26	31.73809	68
2	47	3852.294	47	2119.135	94
3	47	30.96442	44	79.77321	91
4	47	311.2761	46	1078.004	93
5	47	524.6260	47	457.0173	94
6	21	25.52496	14	22.55801	35
7	30	16.30824	14	22.30881	44
8	6	9.928144	4	22.15730	10
9	32	15.33549	24	21.64708	56
10	39	27.22198	27	30.51558	66
11	20	12.94265	23	25.15921	43
12	3	7.538765	36	56.39298	39
13	29	15.46351	29	51.13478	58
14	2	6.716261	0	0.0	2
15	11	10.84408	16	22.98650	27
16	0	0.0	6	11.67103	6
17	0	0.0	5	19.07863	5
18	4	143.3350	6	681.6460	10
19	3	6.051041	0	0.0	3
20	2	13.31319	3	11.78056	5
21	1	5.778820	11	165.2599	12
22	0	0.0	1	11.29501	1
23	3	11.44905	6	16.36813	9
24	0	0.0	1	7.891912	1
25	0	0.0	1	7.384196	1
26	2	5.363450	2	15.11649	4
27	1	22.39242	0	0.0	1
28	0	0.0	0	0.0	0
29	0	0.0	0	0.0	0
30	0	0.0	0	0.0	0
31	0	0.0	0	0.0	0
32	0	0.0	1	6.492136	1
33	0	0.0	0	0.0	0
34	0	0.0	0	0.0	0
35	0	0.0	0	0.0	0
36	0	0.0	0	0.0	0
37	0	0.0	0	0.0	0
Average	11.36	153.35	11.89	135.33	

* counts/100 m^3

Table 8c. Breakdown of species occurrence during sampling day 2.

Species No.	Day Hrs. (8 AM-7 PM) Freqs.	Day Hrs. (8 AM-7 PM) Avg. Density*	Night Hrs. (8 PM-7 AM) Freqs.	Night Hrs. (8 PM-7 AM) Avg. Density	Total Freqs.
1	42	28.06757	17	22.30145	59
2	48	4559.738	43	3692.324	91
3	48	303.1423	43	232.1311	91
4	48	362.7764	42	862.3630	90
5	48	392.6287	43	585.3074	91
6	14	25.79277	18	31.10014	32
7	40	38.60997	30	52.91177	70
8	9	15.99011	3	12.00967	12
9	42	58.05109	21	51.53828	63
10	44	33.88943	34	55.63283	78
11	27	21.58748	21	23.06334	48
12	1	3.828931	30	54.21024	31
13	37	36.88953	20	23.34375	57
14	0	0.0	0	0.0	0
15	32	32.77049	33	34.51804	65
16	2	10.17969	3	16.10184	5
17	3	13.62471	3	21.10454	6
18	4	71.10095	0	0.0	4
19	0	0.0	2	14.53475	2
20	4	6.373543	0	0.0	4
21	6	7.975199	4	41.57392	10
22	0	0.0	0	0.0	0
23	0	0.0	1	21.26700	1
24	0	0.0	2	16.42143	2
25	0	0.0	3	23.41656	3
26	2	8.839287	2	44.81772	4
27	1	5.817045	0	0.0	1
28	2	3.617737	2	20.17264	4
29	1	5.817045	1	41.51929	2
30	3	12.74037	1	16.29977	4
31	2	9.392845	3	16.89806	5
32	0	0.0	0	0.0	0
33	0	0.0	0	0.0	0
34	0	0.0	0	0.0	0
35	0	0.0	0	0.0	0
36	0	0.0	0	0.0	0
37	0	0.0	0	0.0	0
Average	13.78	192.70	11.49	165.89	

* counts/100 m^3

ZOOPLANKTON

Table 8d. Breakdown of species occurrence during sampling day 3.

Species No.	Day Hrs. (8 AM-7 PM)		Night Hrs. (8 PM-7 AM)		Total Freqs.
	Freqs.	Avg. Density*	Freqs.	Avg. Density	
1	38	23.59468	18	32.87732	56
2	44	4441.941	46	7264.504	90
3	44	164.7457	44	227.0827	88
4	44	986.4019	46	446.9727	90
5	44	333.9236	45	425.3203	89
6	31	56.68031	20	45.22246	51
7	28	18.52042	20	61.18584	48
8	9	22.73994	7	17.38574	16
9	44	359.9673	39	270.0901	83
10	35	62.32098	31	84.90485	66
11	9	19.05037	14	21.43140	23
12	0	0.0	30	43.55840	30
13	24	22.34476	39	39.54179	63
14	4	15.61882	2	19.02293	6
15	41	82.03329	41	80.77080	82
16	1	10.11869	1	18.11607	2
17	9	30.20679	7	22.44788	16
18	9	65.71747	6	49.97314	15
19	0	0.0	1	20.30940	1
20	0	0.0	1	13.43098	1
21	8	8.387522	9	42.74628	17
22	2	8.480049	0	0.0	2
23	5	7.396618	2	42.86061	7
24	0	0.0	2	28.22798	2
25	0	0.0	1	16.38860	1
26	14	21.14554	9	25.24638	23
27	1	6.658566	1	6.059505	2
28	20	15.19294	18	26.78960	38
29	3	12.90059	1	21.67839	4
30	30	52.24393	25	103.4366	55
31	3	9.193064	9	42.06306	12
32	0	0.0	0	0.0	0
33	1	10.11869	0	0.0	1
34	4	54.47098	0	0.0	4
35	1	6.243464	0	0.0	1
36	0	0.0	1	11.58583	1
37	0	0.0	1	25.99263	1
Average	14.86	187.27	14.51	259.38	

* counts/100 m^3

Table 9. Revised list of species of ichthyoplankton used in analysis.

	Eggs		Larvae
1.	*Anchoa mitchilli*	1.	*Anchoa* sp.
2.	Labridae	2.	*Gobiosoma ginsburgi*
3.	*Prionotus* sp.	3.	*Scophthalmus aquosus*
4.	*Morone* sp.	4.	*Tautoga onitis*
5.	*Paralichthys*-*Scophthalmus*	5.	*Merluccius bilinearis*
6.	*Peprilus triacanthus*	6.	*Menidia* sp.
7.	*Enchelyopus*-*Urophycis*-*Peprilus*	7.	*Tautogolabrus adspersus*
8.	*Stenotomus*-*Cynoscion*	8.	*Trinectes maculatus*
9.	*Trinectes maculatus*	9.	Clupeidae
10.	*Merluccius bilinearis*	10.	*Syngnathus fuscus*
11.	*Brevoortia tyrannus*	11.	*Stenotomus chrysops*
12.	*Etropus microstomus*		
13.	*Anchoa hepsetus*		

Table 10. Revised list of species of zooplankton used in analysis.

1. *Calanus* sp.
2. Crab zoea
3. *Centropages typicus*
4. Juvenile Mysidacea larvae
5. *Tortanus discaudatus*
6. *Centropages* sp.
7. *Temora longicornus*
8. Unknown Calanoida
9. Unknown medusoid
10. *Centropages hamatus*
11. Unknown Cephalopoda
12. Cumacea
13. *Labidocera aestivalus*
14. *Acartia tonsa*
15. *A. clausi*
16. *Acartia* sp.
17. *Sagitta* sp.
18. Polychaeta larvae
19. Unknown adult Copepoda
20. Stomatopoda larvae
21. Gastropoda larvae

Table 11. ANOVA table for the analysis of the variance due to selected main effects and interactions, showing the partitioning of degrees of freedom for testing.

Observations: N = 275 estimates of the density of each species of fish eggs, fish larvae and zooplankton.

SOURCES OF VARIANCE AND INTERACTIONS	LEVELS	d.f.	
Seasonal (Between Days)...............S	3	2	= 3-1
Diurnal (Between Day and Night).......D	2	1	= 2-1
Nets (Between Net A and Net B)........N	2	1	= 2-1
Interaction (Days) x (Nets)...........SN		2	= (3-1) (2-1)
Interaction (Day-Night) x (Nets)......DN		1	= (2-1) (2-1)
Within Replicates..........		267*	
Total (N-1)..........		274	

---

* The breakdown of d.f. for the "within" or error term is:

$$W = (r-1)(3)(2)(2) + sd + sdn - m = 267$$

where $r = 24$ replicates; $m = 13$ missing observations; and $sd = 2$ and $sdn = 2$ are the d.f. corresponding to the two interactions pooled with the error term.

Table 12. Results of the multivariate analysis of variance for eggs of selected fish species found during June-July 1976 survey. Levels of significance according to Hotelling's criterion for the overall species response, and from F tests for single species responses (total d.f. = 274).
**: highly significant ($\alpha \leq .01$); *: significant ($\alpha \leq .05$); otherwise not significant ($\alpha > .05$).

SOURCE (LEVELS)	Overall Species	*Anchoa mitchili*	Labridae	*Prionotus* sp.	*Morone* sp.	*Paralichthys-Scophthalmus*	*Peprilus triacanthus*	*Enchelyopus-Urophycis-Peprilus*	*Stenotomus-Cynoscion*	*Trinectes maculatus*	*Merluccius bilinearis*	*Prevoortia tyrannus*	*Etropus microstomus*	*A. hepsetus*
Day (3)	.0001 **	.0001 **	.0001 **	.0001 **	.0001 **	.3911	.0001 **	.0001 **	.0242 *	.1155	.0001 **	.0001 **	.0001 **	.0001 **
Day-Night (2)	.0001 **	.0001 **	.0001 **	.0002 **	.0001 **	.0001 **	.0001 **	.0001 **	.1025	.0001 **	.0012 **	.0002 **	.0001 **	.0043 **
Nets (2)	.0022 **	.0001 **	.0026 **	.1929	.0199 *	.3673	.5344	.0449 *	.1000	.3144	.9206	.5693	.0420 *	.5910
Day X Nets	.8632	.7405	.7593	.8851	.8389	.2131	.7002	.5140	.5906	.3205	.7978	.2288	.6179	.4438
Day Night X Nets	.8368	.9480	.3063	.8729	.2326	.9715	.6342	.9224	.8817	.5655	.1901	.9122	.6309	.4539
Mean Density/ 100 m^3	.	8.41	5.41	4.10	3.89	3.33	0.81	2.59	1.82	0.85	0.11	0.42	0.79	0.05
Coefficient of Variability (Density)		6.12	16.86	28.96	25.90	27.00	100.76	39.82	61.34	93.21	266.54	131.06	74.28	403.66

Density data used were previously transformed [$\text{Log}_e\ (X+1)$]

Table 13. Results of multivariate analysis of variance for larvae of selected fish species found during June-July 1976 survey. Levels of significance according to Hotelling's criterion for the overall species response, and from F tests for single species responses (total d.f. = 274).
**: highly significant ($\alpha \leq .01$); *: significant ($\alpha \leq .05$); otherwise not significant ($\alpha > .05$).

SOURCE (LEVELS)	Overall Species	*Anchoa* sp.	*Gobisoma ginsburgi*	*Scophthalmus aquosus*	*Tautoga onitis*	*Merluccius bilinearis*	*Menidia* sp.	*Tautogolabrus adspersus*	*Trinectes maculatus*	Clupeidae	*Syngnathus fuscus*	*Stenotomus chrysops*
Day (2)	.0001 **	.0001 **	.0001 **	.0001 **	.0001 **	.0081 **	.0120 *	.0001 **	.0377 *	.0073 **	.0001 **	.0001 **
Day-Night (2)	.0001 **	.0026 **	.0001 **	.0042 **	.2583	.7579	.0001 **	.2277	.2522	.0016 **	.0640	.0053 **
Nets (2)	.1992	.0106 *	.0276 *	.4125	.3454	.5643	.7653	.0405 *	.0733	.8817	.8478	.1999
Day X Nets	.6155	.0826	.5795	.3500	.4648	.1912	.9046	.0822	.8010	.6610	.4495	.3802
Day-Night X Nets	.8962	.4045	.7562	.3882	.5569	.9299	.6534	.9436	.5922	.1539	.7244	.1888
Mean Density/ 100 m^3		4.61	1.50	0.49	0.50	0.21	0.15	0.56	0.23	0.19	0.32	0.37
Coefficient of Variability (Density)		11.56	42.52	87.05	95.50	159.61	208.54	74.92	164.45	235.85	125.41	96.32

Density data used were previously transformed [$\text{Log}_e(X+1)$]

Table 14.

Results of multivariate analysis of variance for selected species of zooplankton found during June-July 1976 survey. Levels of significance according to Hotelling's criterion for the overall species response, and from F tests for single species responses (total d.f. - 274).
**: highly significant ($\alpha \le .01$); *: significant ($\alpha \le .05$); otherwise not significant (α .05).

SOURCE (LEVELS)	Overall Species	*Calanus* sp.	Crab zoea	*Centropages typicus*	Juvenile Mysidacea larvae	*Tortanus discaudatus*	*Centropages* sp.	*Temora longicornus*	Unknown Calanoida	Unknown meausoid	*Centropagus namatus*
Day (3)	.0001 **	.0424 *	.0001 **	.0001 **	.0830	.0001 **	.0001 **	.0001 **	.2150	.0001 **	.0001 **
Day-Night (2)	.0001 **	.0001 **	.2982	.0204 *	.0009 **	.0242 *	.1111	.0781	.1328	.0001 **	.0076 **
Nets (2)	.4076	.2323	.2694	.0954	.7512	.1453	.1137	.2143	.0287 *	.2125	.3485
Day X Nets	.9615	.8621	.8743	.2228	.9729	.4964	.8457	.6964	.6383	.2309	.5504
Day-Night X Nets	.8482	.5093	.6120	.4898	.2372	.3122	.5262	.5709	.1829	.4804	.7635
Mean Density/ 100 m^3		2.12	8.02	4.75	6.35	5.98	1.41	1.86	.38	3.07	2.78
Coefficient of Variability (Density)		68.36	9.52	20.25	15.93	13.72	118.65	86.91	252.78	51.78	60.46

(continued)

Density data used were previously transformed $[\text{Log}_e(X+1)]$

Table 14 (continued)

SOURCE (LEVELS)	Unknown Cephalopoda	Cumacea	*Labidocera aestivalus*	*Acartia tonsa*	*A. clausi*	*Acartia* sp.	*Sagitta* sp.	Polychaeta larvae	Unknown adult Copepoda	Stomatopoda larvae	Gastropoda larvae
Days (3)	.0008 **	.1729	.1430	.0001 **	.4309	.0090 **	.0496 *	.2736	.0001 **	.0001 **	.0001 **
Day-Night (2)	.2369	.0001 **	.1698	.1405	.0357 *	.4126	.2833	.0043	.5825	.8906	.5838
Nets (2)	.4953	.4186	.7791	.0857	.8014	.3296	.3167	.8635	.3368	.5277	.7729
Days X Nets	.5358	.1484	.4625	.7096	.2432	.4002	.6019	.6885	.5403	.7528	.4367
Day-Night X Nets	.3035	.6800	.1121	.7684	.3593	.7852	.2514	.5761	.4428	.1629	.3012
Mean Density/ 100 m^3	1.20	1.33	2.04	2.25	0.12	0.28	0.44	0.44	0.32	0.44	0.76
Coefficient of Variability (Density)	121.14	98.70	80.34	64.39	454.06	310.48	299.23	263.18	277.78	207.70	155.63

Table 15. Summary of results of the harmonic regression analysis.

Source of Variation	Step 1 (First Harmonic)		Step 2 (First & Second Harmonics)	
	Sum of Squares	% of Total Variance	Sum of Squares	% of Total Variance
Scatter about curve (or about regression)	120,164.08	40.73	192,852.62	65.37
Between Replicates (days)	15,300.29	5.18	15,300.29	5.19
Replicates Within Scatter (error term)	159,552,38	54.08	86,863.83	29.44
Total	295,016.75	100.00	295,016.75	100.00

Parameters Fitted	Periods for Maximum Responses
a_0 = -0.8956	
a_1 = 5.4850	23.99 hrs. in first harmonic curve
a_2 = 5.1328	
b_1 = -1.4108	12.83 hrs. in second harmonic curve
b_2 = 20.2723	

F tests for the Significance of Replicates or "Days" Effect

Step 1 (first harmonic)	$F = 2.109$	(d.f. = 2, 44) non-significant
Step 2 (first and second harmonic)	$F = 3.648$	(d.f. = 2, 40) significant ($\alpha = 0.05$)

This test indicates that diurnal response (24 hrs. period) was similar over the three days, while tidal response (12.8 hrs. period) was different. This can be attributed to the real time scale which made out of phase the tidal cycles over the three days.

Table 16. Percent of variance explained by the ANOVA linear model for select species of eggs, larvae, and zooplankton. [Where a significant response to the nets effect was found, it is indicated by **(P < 0.1) or * (P < .05)].

	PER CENTS		
	Total Variance Explained (R^2)	Seasonal Var. Component	Seasonal Var. Component
Eggs Spp. # 1**	57	31	23
# 2**	34	8	23
# 3	15	10	4.5
# 4*	49	12	36
# 5	7.3	0.6	5.3
# 7*	46	12	33
Larvae Spp. # 1*	49	45	2
# 2*	42	31	10
# 3	14	11	3
# 4	17	15	0.4
# 7*	69	67	0.2
Zoopl. Spp. # 1	20.9	18.3	1.9
# 2	19	18	0.3
# 3	25	21	1.5
# 4	6	2	4
# 5	24.7	22	1.5
# 9	48	43	4.4
# 10	10.4	7.2	2.4
# 12	50	0.8	49
# 14	42	41	0.5

SECTION VI

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APPENDIX I

STATISTICAL LINEAR MODELS IN THE COLLECTION AND ANALYSIS OF ECOLOGICAL DATA

There seems to be no limit to the demands for more and more data concerning the problems of prediction and protection of the marine and estuarine environments. From the volume of data being generated in some studies, the ultimate goal in monitoring and baseline establishment appears to be to measure everything, everywhere, continuously. It should be recognized that even if this virtually infinite amount of data were gathered, there is no guarantee that it would lead to complete understanding or predictive inferences from a given system. Thus, any environmental monitoring or baseline study should be practical and feasible within reasonable time and cost constraints. However, the data gathered must be accurate, pertinent to the problem at hand, concise and purposefully collected.

It is evident from the above that proper sampling of the marine environment is an important step in monitoring and impact assessment. For example, even though analytical methods for estimating certain environmental parameters may be highly accurate and precise, if the sample being analyzed is not representative, the data resulting from the analysis is relatively worthless.

A sampling program for any environmental monitoring or baseline study must consider explicitly the following items: a) the number of samples required; b) sampling frequency; c) parameters to be measured; and d) sampling locations. These items are premised on some accepted definition of the level of perturbation or impact which is ecologically significant. It is recognized that a complete environmental assessment program encompasses a relatively comprehensive characterization (physical, chemical, biological) of a system, and includes determination of the potential impacts of pollutants or environmental changes on human health and ecological systems. Lucas (1976) and Eberhart (1975) have provided a review of some of the difficulties in assessing impacts and have proposed some models as bases for taking and analyzing environmental data. It is our belief that programs with more limited objectives of characterizing existing conditions or identifying previously defined impacts or changes can be developed as subsets of larger environmental assessment and monitoring programs. It is our objective to briefly describe some aspects of the design and analysis of such experiments to answer some specific questions on sampling with particular reference to ichthyoplankton.

Most biotic elements of the environment are highly variable and ever-changing. They must be sampled with sufficient intensity to determine the course of such changes in time and space. Empirical evidence to date concerning ichthyoplankton, as well as juvenile and adult fishes suggests that several years of sampling may be necessary to detect reasonable changes in these populations.

STATISTICAL METHODOLOGY

There have been two general kinds of statistical methodology applied to environmental impact analysis and monitoring. They are linear model analysis and time-series analysis.

Time-series analysis will not be considered in detail in this report. However, it will be briefly mentioned. In time-series analysis, the correlation of a response variable to past observations is taken into account in the formulation of a statistical model. Statistical time-series analysis has been treated in several excellent books including: Anderson (1971), Box and Jenkins (1970), and Nelson (1973). The treatment of the methodology and time-series is comprehensive in these references, and the reader is referred to them for details. Our limited understanding of the methodology suggests that relatively large amounts of data gathered at frequent and evenly spread sampling intervals are highly desirable for this methodology to be effective in most instances.

The general linear model analysis is described at various levels of detail in several statistics books, such as Cochran and Cox (1957), Davies (1954), Federer (1955), Kempthorne (1972), Sheffe (1959), and Snedecor and Cochran (1967). This linear model approach includes analysis of variance and regression analysis. In this approach variations in a response variable measured over time and space are decomposed into assignable sources of variations and these variations are assumed to be additive. Tests of significance, such as F-tests or variance ratio tests to determine the change in the mean value of some variable from several sample events, are based on certain assumptions such as a normal probability density and independent and homogeneous variance (Scheffe, 1959). Data from samples taken over time, frequently do not conform to these assumptions. Nonstationary elements, such as seasonal or diurnal, and tidal components are often present, and the data may be highly correlated in time.

In the linear model approach time, space and sampling locations, along with replications, become a part of a planned experimental design. As a means for considering spatial and temporal variability in the linear model the spatial and temporal distributions of biota (i.e., ichthyoplankton) are treated as a sum of responses due to assignable sources of factor levels. In addition, transformations of the response variable are sometimes used to achieve homogeneity of variances. Finally, because one can expect certain physical and biological data to be correlated, these relationships can be effectively utilized by carrying out multivariate analyses of variance and covariance analyses.

In carrying out the linear model approach to monitoring and impact assessment, the method involves formulating hypotheses or linear contrasts for carrying out the statistical tests. Among these contrasts one tests for main effects due to a defined factor and the interaction of factors of interest.

SCHEME FOR ESTABLISHING SAMPLING STATIONS

We will illustrate the use of a simple linear model by an example which relates to deciding where to establish monitoring stations along a cross-sectional area of an estuary which is of interest. For simplicity we will assume that cost constraints limit the number of samples to about 50. Our prior knowledge of the problem suggests that we should be concerned about the depth distribution of the given organism (say winter flounder larvae). Table 1 gives a sketch of the data as they might be gathered for this analysis. No time effects are considered in this analysis.

The data in Table 1 illustrate an outline for triplicate determinations of a given ichthyoplankton larval species for five locations along the cross-section of an estuary at three depth levels. Since each station location has three replicate samples at each depth, the classifications "depths" and "locations" are completely crossed, while the triplicate determinations provide three replications for each combination of depth and location. In the above table there are three columns corresponding to depths, five rows corresponding to the five locations, and there are 15 cells each containing three replicate observations.

In the general case there are $x_{ij\alpha}$ observations, $i - 1,\ldots, p$ rows, $j = 1,\ldots, q$ columns, $\alpha = 1,\ldots, \eta$ replicates. The model for the analysis is assumed to be:

$$x_{ij\alpha} = \mu + \xi_i + \eta_j + \lambda_{ij} + \delta_{ij} \quad .$$

In the above model, μ is the mean, ξ represents row effects (location variability), and η_j represents column effects (depth variability). The interaction effects λ_{ij} represent any variations which may be peculiar to a particular combination of station and depth, and the effects $\delta_{ij\alpha}$ are normally distributed random components with average value zero for each ij.

The general analysis of variance table (Table 2) for this particular model is shown. From this table the partitioning of the degrees of freedom can be determined as well as the appropriate tests of significance determined. Two points can be made concerning this model. They are: (1) the variation between sample locations can be estimated, and (2) the systematic variations between sample locations can be eliminated from the study of other effects, i.e. depth.

Assuming that an approach such as the above has been applied to establishing whether one or more sampling stations are required for the monitoring program we now turn to a detailed analysis of a single station, which was a major component of the work which has been performed to date.

Table I-1. Numbers of larvae obtained by sampling different depths across an estuary.

Stations on Cross Section	Number of Larvae		
	Surface	Mid-depth	Bottom
1a	-	-	-
1b	-	-	-
1c	-	-	-
2a	-	-	-
2b	-	-	-
2c	-	-	-
3a	-	-	-
3b	-	-	-
3c	-	-	-
4a	-	-	-
4b	-	-	-
4c	-	-	-
5a	-	-	-
5b	-	-	-
5c	-	-	-

Table 2. General analysis of variance table for first stage monitoring station selection (basis for Table 1 layout).

Source of Estimate	Sum of Squares	df	Aver. Value of Variance Estimate
Between rows	$S_i = n_q \Sigma_i (\bar{x}_{i.} - \bar{x})^2$	p-1	$\sigma^2 + n(1 - \frac{q}{Q}) \sigma_\lambda{}^2 + n_q \sigma_\xi{}^2$
Between columns	$S_j = nq \Sigma_j (\bar{x}_{i.} - \bar{x})^2$	q-1	$\sigma^2 + n(1 - \frac{p}{P}) \sigma_\lambda{}^2 + n_p \sigma_\eta{}^2$
Interaction	$S_{ij} = n \Sigma_{ij} (\bar{x}_{ij} - \bar{x}_{i.} - x_{.j} + \bar{x})^2$	(p-1)(q-1)	$\sigma^2 + n\sigma_\lambda{}^2$
Replicates	$S_{\alpha(ij)} = \Sigma_{ij\alpha} (\bar{x}_{ij\alpha} - \bar{x}_{ij})^2$	$N-p_q$	σ^2
TOTAL	$S = \Sigma_{ij} (x_{ij\alpha} - \bar{x})^2$	N-1	

In the above table:

$\bar{x}_{i.} \equiv$ row mean, $\bar{x}_{.j} \equiv$ column mean;

$\bar{x}_{ij} \equiv$ class mean;

p and Q refer to population sizes, large with respect to q in this case.

APPENDIX II

EXCERPTS FROM A DESCRIPTION OF LAB PROCEDURES SUBMITTED IN A RECENT PROPOSAL BY MARINE RESEARCH, INC.

Subsamples for ichthyoplankton (fish eggs and larvae) analysis will be washed with filtered seawater, using a sieve of the same size mesh as the net used in the field, to remove excess formalin. The sample is then placed in a beaker of seawater, enough residual formalin remaining in the plankton to prevent deterioration for several days.

Samples in which the numbers of ichthyoplankton are low are counted entirely. For counting very abundant forms, the sample is split into fractions, the size of fraction being determined by the numbers present of a given type of fish egg or larva. We use a splitter of our own design.

Small portions of the sample are poured into special trays, also of our design, which are divided by baffles and ruled markings in such a way that the entire portion can be systematically examined under a dissecting microscope with little risk of any organism being counted twice or going uncounted. Numbers are recorded on multiple tally counters, and then transferred to data cards for subsequent coding on computer cards, together with station data, including flowmeter readings.

Representative specimens, as well as any presenting problems in identification, are removed to a reference collection. Any such removals are noted on the sample data cards and on a tag stored in the samples.

About 15 percent of the samples, chosen at random from each series, are recounted, the technician carrying out the recount in no case having made the first count. Any significant errors detected in this way are corrected appropriately.

Following counting, the samples are returned to a 10 percent buffered solution of formalin in seawater, together with all station tables and pertinent notes (made on herbarium paper to prevent deterioration), sealed with tape, and stored for future reference. Two logs of all data are kept, in separate locations, to insure against accidental loss.

Extensive analyses which Marine Research, Inc. has carried out covering all phases of ichthyoplankton sampling, taking into account replication in the field, different sizes of aliquots ("splits") counted in the laboratory, different species of eggs and larvae, as well as operator error, show that combined subsampling and operator error in the laboratory is small relative to the variability between replicate samples taken in the field at a single station. When rules that we have developed for determining subsample size are followed, combined subsampling and operator error average about 10 percent. Typically, in the coastal New England waters where we have worked, counts from a single oblique tow (60 cm bongo net; one net of a pair) can be assigned the confidence limits shown in the following table (combines all error sources):

Table 1. 95% confidence intervals for a single ichthyoplankton sample at a single station, based on repeated counts of a random selection of midsummer samples from Narragansett Bay. (Source: MRI, 1974. Narragansett Bay Ichthyoplankton Survey, Final Report)

	Whole Sample	1/16th Aliquot
Eggs	79-126%	71-140%
Larvae	66-151%	59-168%

For the analysis of the zooplankton, the samples were filtered through a screen with an average mesh opening of 58 microns and resuspended in a small amount of the filtrate. Three 1 ml aliquots were drawn off and each was analyzed separately on Sedgwick-Rafter slides. From previous experience, it has been determined that a concentration of approximately 500 organisms per slide produces an acceptable margin of error with a reasonable expenditure of time and effort.

This was attempted here. However, the presence of large numbers of adult shrimp and polychaetes in approximately one-third to one-half of the samples made the analysis of these samples at the desired concentration impossible. The zooplankton in these samples were analyzed in the best manner possible, and the Chaetognatha and non-planktonic organisms 5 millimeters or greater in length were analyzed separately and reported separately.

After analysis, the samples and the filtrate were returned to the original bottles and additional formalin added.

In order to check for biases introduced in the lab, 30 randomly chosen samples were recounted for each, egg and larvae, and 25 for zooplankton. Means comparisons of the actual sample counts against recounts of the same samples were done by performing a simple one-way analysis of variance for each species. With only three exceptions no significant differences existed. However, in these three cases the densities were extremely low and the coefficients of variability very high, thus invalidating the tests. For each group (eggs, larvae, and zooplankton) the means of sample counts were compared to the recount means over all species in a multivariate one-way analysis of variance. For eggs the overall means difference was not significant. For larvae and zooplankton, the hypothesis matrices were near singular because of the many zero frequencies in the original data, consequently no multivariate test could be performed for these two groups.

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 1 - EVALUATION OF THE WATER LEVEL FUNCTION AND ITS SLOPE

DECIMAL TIME (HOURS)	TIME (MIN.)	ANGLE (DEG)	ANGLE (RAD)	WATER LEVEL (METERS)	SLOPE (M./U.T.)	DECIMAL TIME (HOURS)
8.000	480	80.886	1.4117	1.181	0.097	8.000
8.267	496	90.000	1.5708	1.189	0.000	8.267
9.000	540	115.063	2.0082	1.131	-0.258	9.000
10.000	600	149.240	2.6047	0.891	-0.524	10.000
11.000	660	183.418	3.2012	0.543	-0.609	11.000
12.000	720	217.595	3.7977	0.207	-0.483	12.000
13.000	780	251.772	4.3942	0.000	-0.191	13.000
13.533	812	270.000	4.7124	-0.030	-0.000	13.533
14.000	840	282.029	4.9223	-0.015	0.149	14.000
15.000	900	307.804	5.3722	0.120	0.439	15.000
16.000	960	333.580	5.8221	0.367	0.641	16.000
17.000	1020	359.355	6.2719	0.678	0.716	17.000
18.000	1080	385.131	6.7218	0.990	0.648	18.000
19.000	1140	410.907	7.1717	1.242	0.452	19.000
20.000	1200	436.682	7.6215	1.383	0.165	20.000
20.517	1231	450.000	7.8540	1.402	0.000	20.517
21.000	1260	465.219	8.1196	1.376	-0.196	21.000
22.000	1320	496.705	8.6691	1.167	-0.544	22.000
23.000	1380	528.192	9.2187	0.808	-0.731	23.000
24.000	1440	559.679	9.7682	0.404	-0.703	24.000
25.000	1500	591.166	10.3178	0.074	-0.468	25.000
26.000	1560	622.653	10.8673	-0.085	-0.096	26.000
26.233	1574	630.000	10.9956	-0.091	-0.000	26.233
27.000	1620	650.394	11.3515	-0.050	0.228	27.000
28.000	1680	676.995	11.8158	0.117	0.479	28.000
29.000	1740	703.596	12.2801	0.379	0.629	29.000
30.000	1800	730.197	12.7443	0.680	0.645	30.000
31.000	1860	756.797	13.2086	0.956	0.525	31.000
32.000	1920	783.398	13.6729	1.150	0.293	32.000
33.000	1980	810.000	14.1372	1.219	0.000	33.000

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 2 - EVALUATION OF THE WATER LEVEL FUNCTION AND ITS SLOPE

DECIMAL TIME (HOURS)	TIME (MIN.)	ANGLE (DEG)	ANGLE (RAD)	WATER LEVEL (METERS)	SLOPE (M./U.T.)	DECIMAL TIME (HOURS)
3.000	180	-106.087	-1.8516	-0.065	-0.186	3.000
3.617	217	-90.000	-1.5708	-0.091	0.000	3.617
4.000	240	-80.000	-1.3963	-0.081	0.116	4.000
5.000	300	-53.913	-0.9410	0.037	0.395	5.000
6.000	360	-27.826	-0.4857	0.266	0.593	6.000
7.000	420	-1.739	-0.0304	0.559	0.670	7.000
8.000	480	24.348	0.4249	0.856	0.611	8.000
9.000	540	50.435	0.8803	1.096	0.427	9.000
10.000	600	76.522	1.3356	1.231	0.156	10.000
10.517	631	90.000	1.5708	1.250	0.000	10.517
11.000	660	106.262	1.8546	1.224	-0.179	11.000
12.000	720	139.907	2.4418	1.022	-0.490	12.000
13.000	780	173.551	3.0290	0.681	-0.636	13.000
14.000	840	207.196	3.6163	0.317	-0.569	14.000
15.000	900	240.841	4.2035	0.051	-0.312	15.000
15.867	952	270.000	4.7124	-0.030	-0.000	15.867
16.000	960	273.461	4.7728	-0.029	0.040	16.000
17.000	1020	299.423	5.2259	0.056	0.329	17.000
18.000	1080	325.384	5.6790	0.259	0.552	18.000
19.000	1140	351.346	6.1321	0.539	0.663	19.000
20.000	1200	377.307	6.5852	0.840	0.640	20.000
21.000	1260	403.269	7.0384	1.100	0.488	21.000
22.000	1320	429.230	7.4915	1.267	0.238	22.000
22.800	1368	450.000	7.8540	1.311	0.000	22.800
23.000	1380	456.687	7.9707	1.306	-0.082	23.000
24.000	1440	490.124	8.5543	1.146	-0.452	24.000
25.000	1500	523.560	9.1378	0.808	-0.672	25.000
26.000	1560	556.997	9.7214	0.405	-0.670	26.000
27.000	1620	590.433	10.3050	0.069	-0.447	27.000
28.000	1680	623.870	10.8886	-0.087	-0.075	28.000
28.183	1691	630.000	10.9956	-0.091	-0.000	28.183
29.000	1740	650.417	11.3519	-0.048	0.239	29.000
30.000	1800	675.417	11.7882	0.113	0.408	30.000
31.000	1860	700.417	12.2246	0.364	0.646	31.000
32.000	1920	725.417	12.6609	0.659	0.683	32.000
33.000	1980	750.417	13.0972	0.942	0.591	33.000
34.000	2040	775.417	13.5336	1.159	0.389	34.000
35.000	2100	800.417	13.9699	1.271	0.114	35.000
35.383	2123	810.000	14.1372	1.280	0.000	35.383

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 3 - EVALUATION OF THE WATER LEVEL FUNCTION AND ITS SLOPE

DECIMAL TIME (HOURS)	TIME (MIN.)	ANGLE (DEG)	ANGLE (RAD)	WATER LEVEL (METERS)	SLOPE (M./U.T.)	DECIMAL TIME (HOURS)
3.000	180	67.771	1.1828	1.114	0.225	3.000
3.683	221	90.000	1.5708	1.158	0.000	3.683
4.000	240	100.301	1.7506	1.149	-0.106	4.000
5.000	300	132.831	2.3183	1.000	-0.404	5.000
6.000	360	165.361	2.8861	0.714	-0.575	6.000
7.000	420	197.892	3.4539	0.381	-0.566	7.000
8.000	480	230.422	4.0216	0.106	-0.379	8.000
9.000	540	262.952	4.5894	-0.026	-0.073	9.000
9.217	553	270.000	4.7124	-0.030	-0.000	9.217
10.000	600	290.047	5.0623	0.015	0.256	10.000
11.000	660	315.640	5.5089	0.194	0.534	11.000
12.000	720	341.232	5.9556	0.476	0.707	12.000
13.000	780	366.824	6.4023	0.805	0.741	13.000
14.000	840	392.417	6.8490	1.117	0.630	14.000
15.000	900	418.009	7.2956	1.350	0.396	15.000
16.000	960	443.601	7.7423	1.458	0.083	16.000
16.250	975	450.000	7.8540	1.463	0.000	16.250
17.000	1020	471.485	8.2290	1.413	-0.262	17.000
18.000	1080	500.132	8.7290	1.206	-0.550	18.000
19.000	1140	528.779	9.2289	0.886	-0.703	19.000
20.000	1200	557.426	9.7289	0.532	-0.683	20.000
21.000	1260	586.073	10.2289	0.231	-0.497	21.000
22.000	1320	614.720	10.7289	0.056	-0.189	22.000
22.533	1352	630.000	10.9956	0.030	-0.000	22.533
23.000	1380	643.658	11.2340	0.047	0.137	23.000
24.000	1440	672.927	11.7448	0.186	0.394	24.000
25.000	1500	702.195	12.2556	0.433	0.551	25.000
26.000	1560	731.463	12.7664	0.725	0.568	26.000
27.000	1620	760.731	13.2773	0.987	0.439	27.000
28.000	1680	789.999	13.7881	1.154	0.198	28.000
28.683	1721	810.000	14.1372	1.189	0.000	28.683
29.000	1740	820.332	14.3175	1.179	-0.112	29.000
30.000	1800	852.960	14.8870	1.021	-0.426	30.000
31.000	1860	885.589	15.4564	0.719	-0.605	31.000
32.000	1920	918.217	16.0259	0.369	-0.594	32.000
33.000	1980	950.845	16.5954	0.079	-0.395	33.000
34.000	2040	983.473	17.1640	-0.057	-0.071	34.000
34.200	2052	990.000	17.2787	-0.061	-0.000	34.200

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 1 - HOURLY WATER LEVEL AND ITS INSTANTANEOUS RATE OF CHANGE OR TIDAL FACTOR

TIME	WATER LEVEL (METERS)	TIDAL FACTOR (M./UNIT TIME)
0800	1.181	0.097
0900	1.131	-0.258
1000	0.891	-0.524
1100	0.543	-0.609
1200	0.207	-0.483
1300	0.000	-0.191
1400	-0.015	0.149
1500	0.120	0.439
1600	0.367	0.641
1700	0.678	0.716
1800	0.990	0.648
1900	1.242	0.452
2000	1.383	0.165
2100	1.376	-0.196
2200	1.167	-0.544
2300	0.808	-0.731
2400	0.404	-0.703
0100	0.074	-0.468
0200	-0.085	-0.096
0300	-0.050	0.228
0400	0.117	0.479
0500	0.379	0.629
0600	0.680	0.645
0700	0.956	0.525

NOTE: WATER LEVEL IS REFERRED TO THE MEAN W.LEVEL IN THE BAY

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 2 - HOURLY WATER LEVEL AND ITS INSTANTANEOUS RATE OF CHANGE OR TIDAL FACTOR

TIME	WATER LEVEL (METERS)	TIDAL FACTOR (M./UNIT TIME)
0800	0.856	0.611
0900	1.096	0.427
1000	1.231	0.156
1100	1.224	-0.179
1200	1.022	-0.490
1300	0.681	-0.636
1400	0.317	-0.569
1500	0.051	-0.312
1600	-0.029	0.040
1700	0.056	0.329
1800	0.259	0.552
1900	0.539	0.663
2000	0.840	0.640
2100	1.100	0.488
2200	1.267	0.238
2300	1.306	-0.082
2400	1.146	-0.452
0100	0.808	-0.672
0200	0.405	-0.670
0300	0.069	-0.447
0400	-0.087	-0.075
0500	-0.048	0.239
0600	0.113	0.488
0700	0.364	0.646

NOTE: WATER LEVEL IS REFERRED TO THE MEAN W.LEVEL IN THE BAY

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

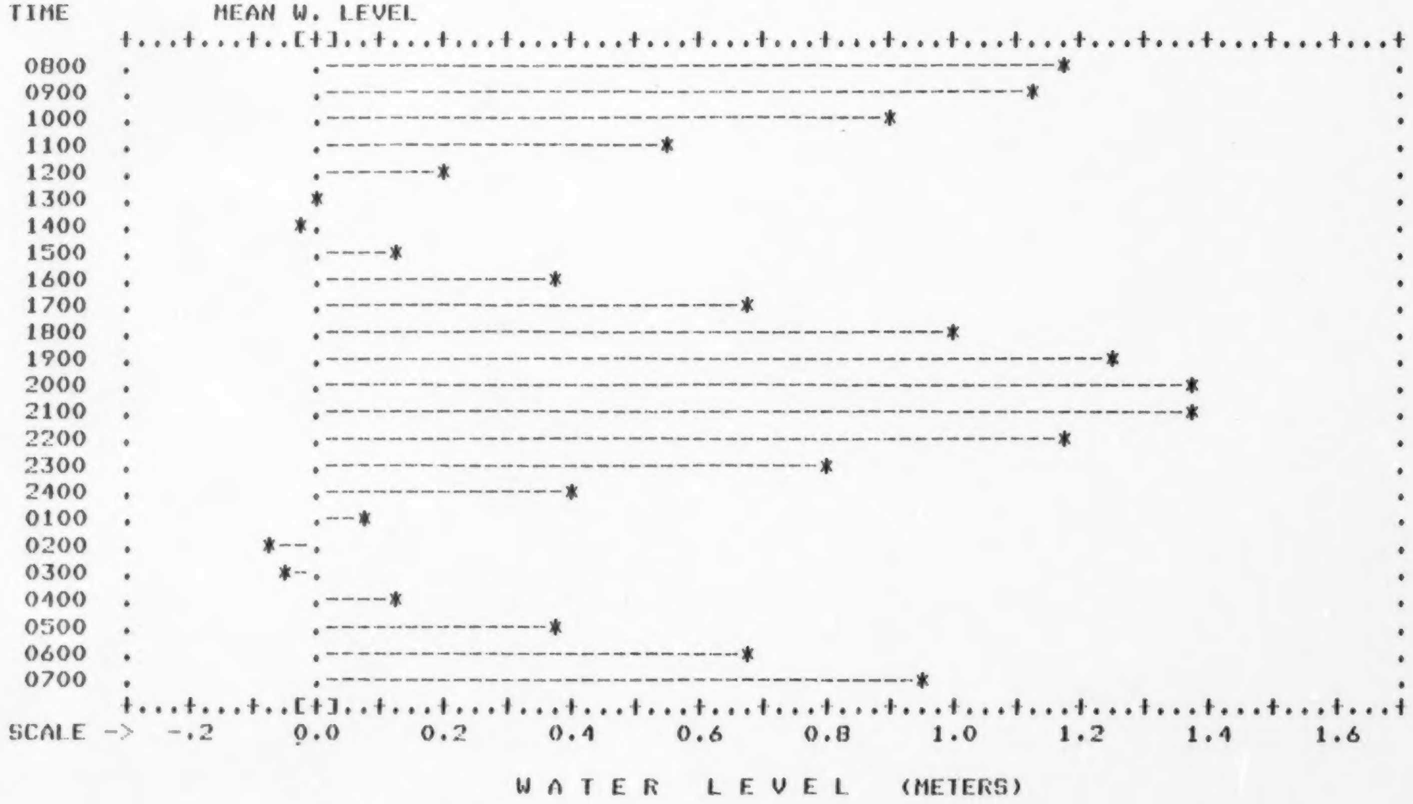
SAMPLING DAY NO. 3 - HOURLY WATER LEVEL AND ITS INSTANTANEOUS RATE OF CHANGE OR TIDAL FACTOR

TIME	WATER LEVEL (METERS)	TIDAL FACTOR (M./UNIT TIME)
0800	0.106	-0.379
0900	-0.026	-0.073
1000	0.015	0.256
1100	0.194	0.534
1200	0.476	0.707
1300	0.805	0.741
1400	1.117	0.630
1500	1.350	0.396
1600	1.458	0.083
1700	1.413	-0.262
1800	1.206	-0.550
1900	0.886	-0.703
2000	0.532	-0.683
2100	0.231	-0.497
2200	0.056	-0.189
2300	0.047	0.137
2400	0.186	0.394
0100	0.433	0.551
0200	0.725	0.568
0300	0.987	0.439
0400	1.154	0.198
0500	1.179	-0.112
0600	1.021	-0.426
0700	0.719	-0.605

NOTE: WATER LEVEL IS REFERRED TO THE MEAN W.LEVEL IN THE BAY

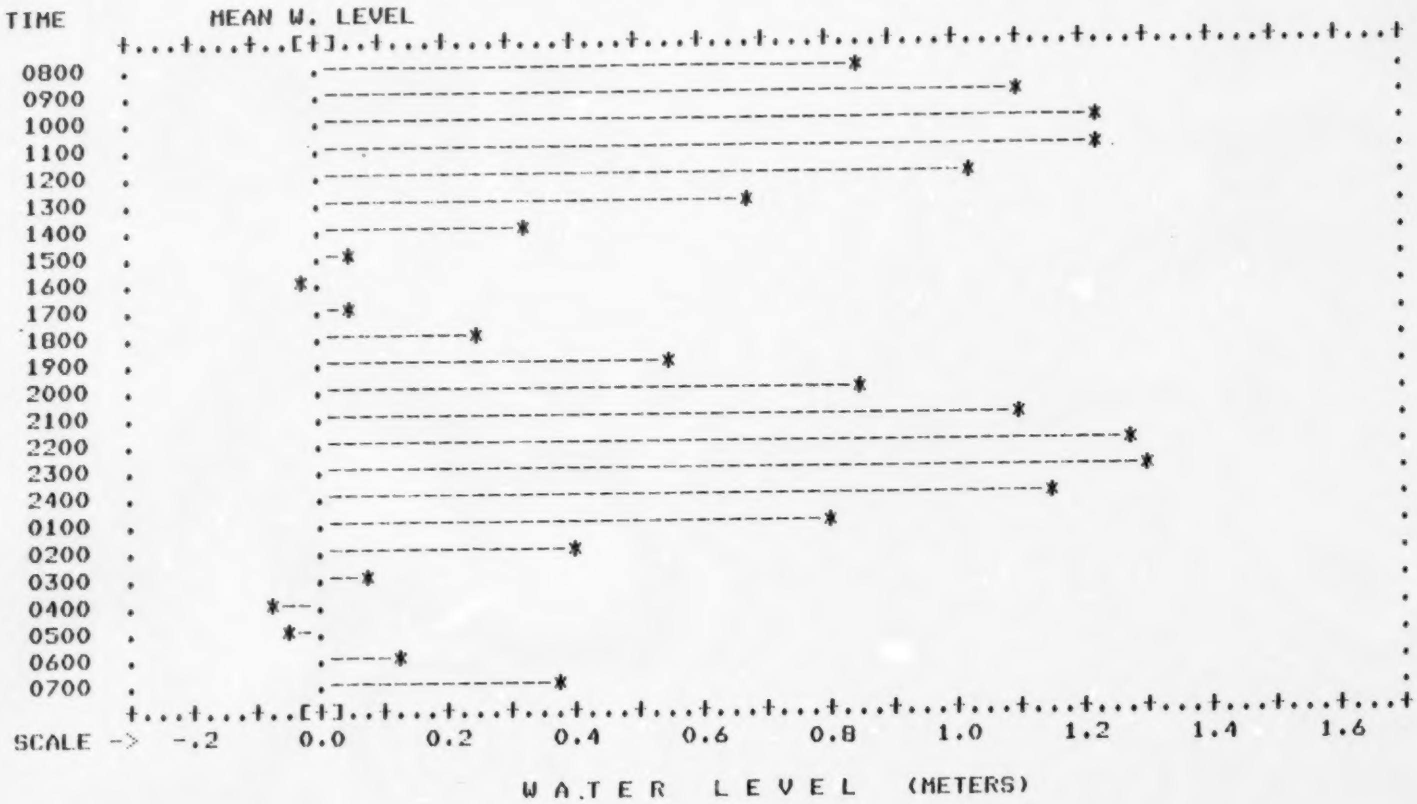
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE WATER LEVEL VS. TIME DURING SAMPLING DAY NO. 1



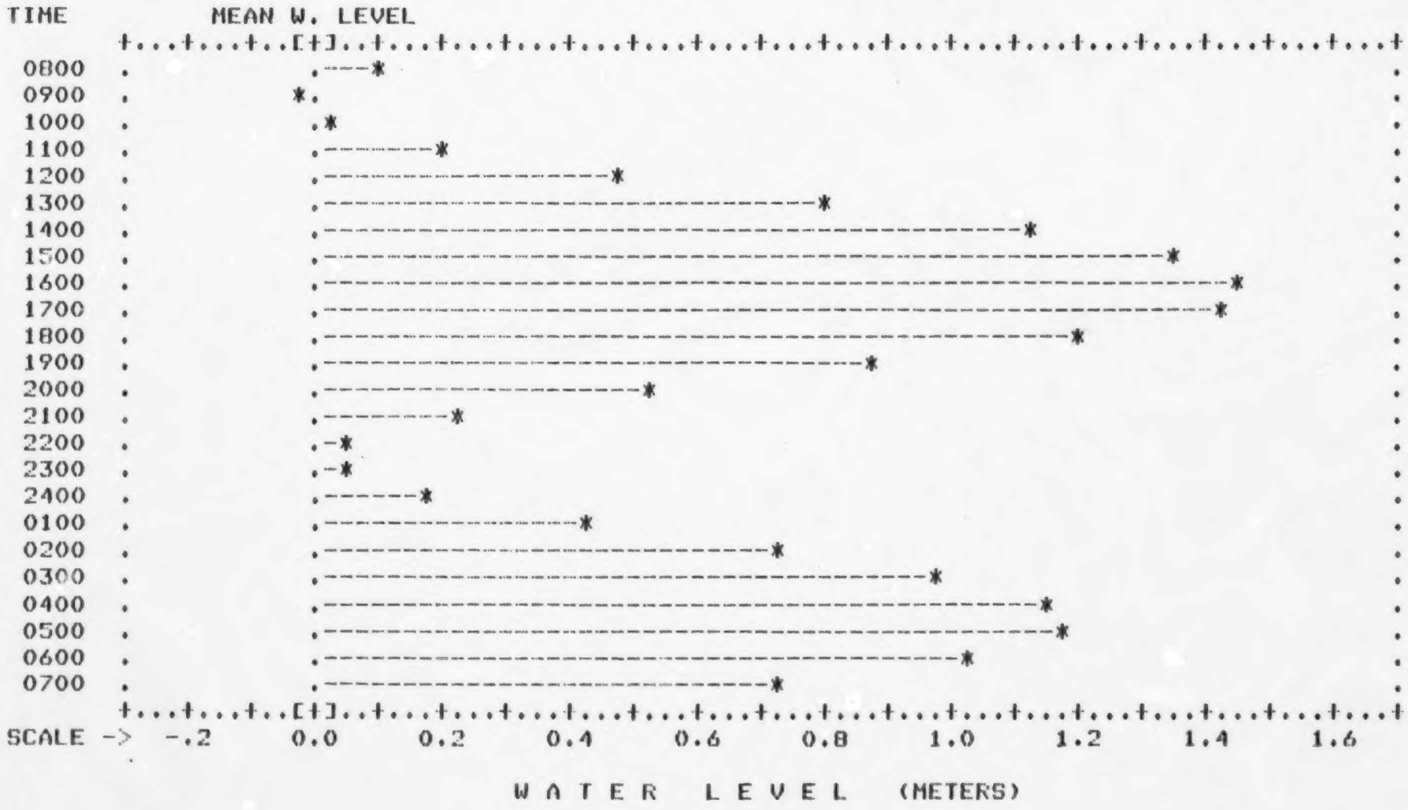
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE WATER LEVEL VS. TIME DURING SAMPLING DAY NO. 2



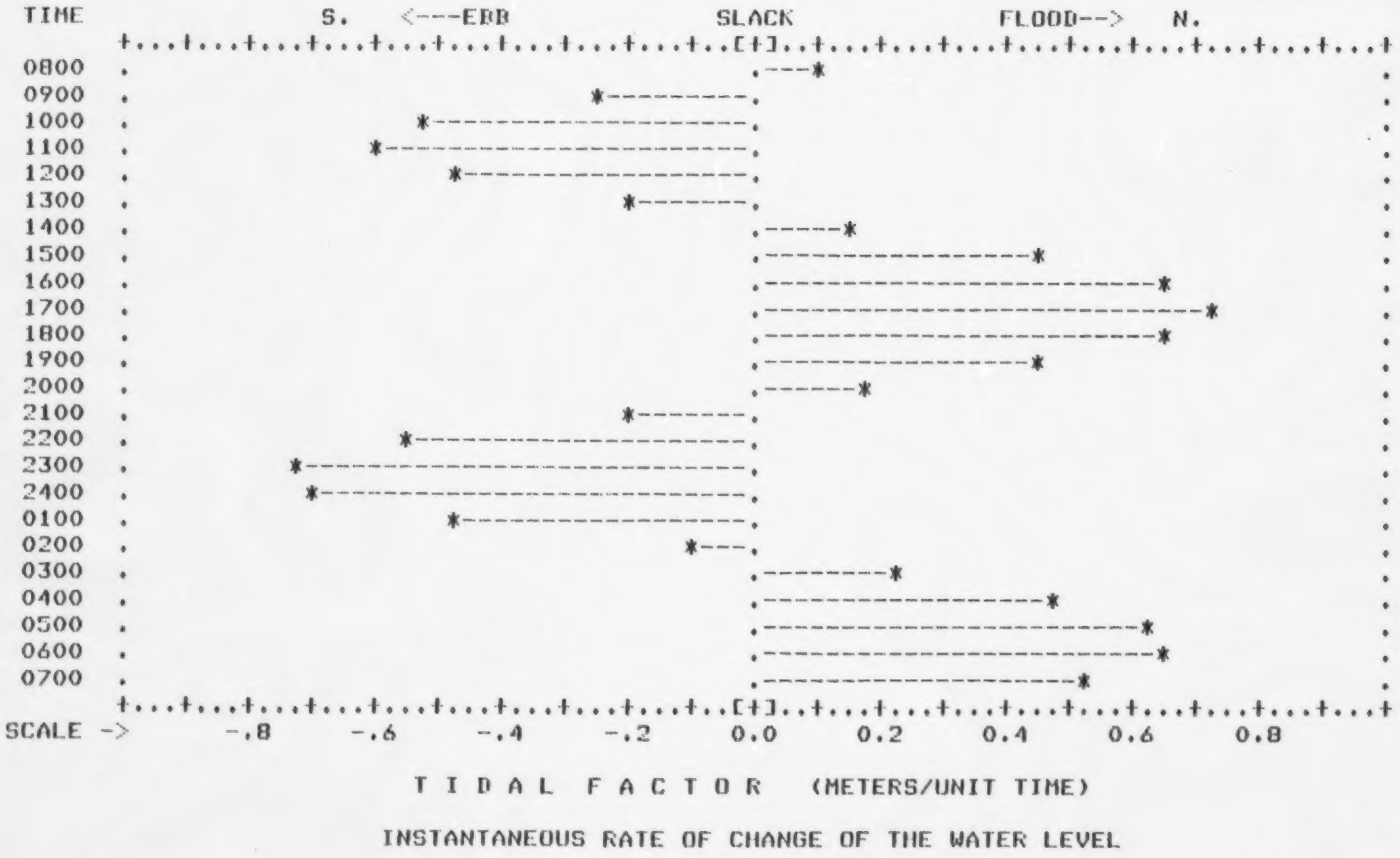
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE WATER LEVEL VS. TIME DURING SAMPLING DAY NO. 3



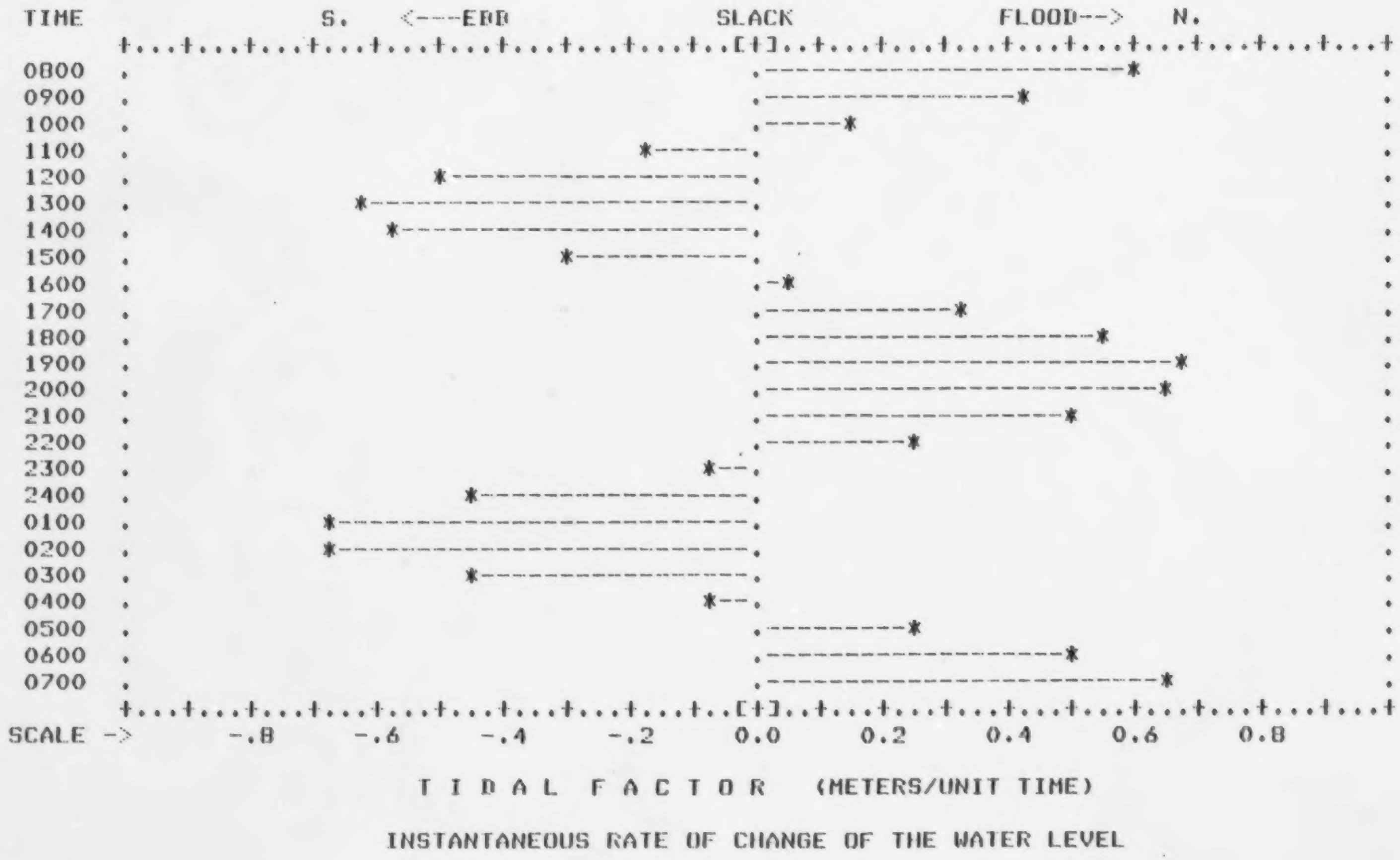
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE TIDAL FACTOR VS. TIME DURING SAMPLING DAY NO. 1



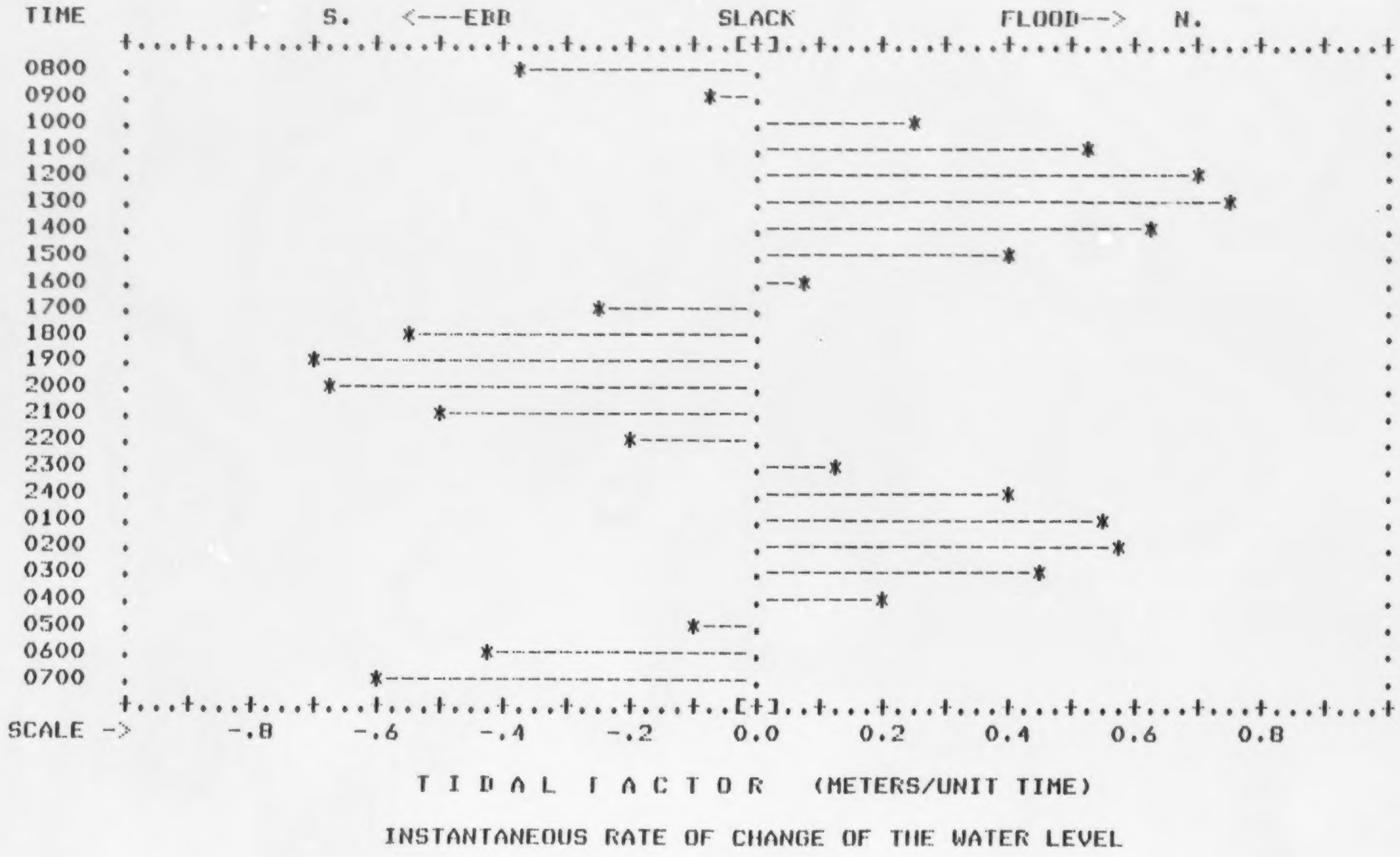
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE TIDAL FACTOR VS. TIME DURING SAMPLING DAY NO. 2



1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE TIDAL FACTOR VS. TIME DURING SAMPLING DAY NO. 3



1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

TEMPERATURES RECORDED AT VARIOUS DEPTHS DURING SAMPLING DAY NO. 1 - (TEMP. IN DEG. F.)

DEPTH IN METERS -> DAY	TIME	0.0	3.00	5.00	7.00	10.00	13.00	16.00	TIME	WEIGHED MEAN TEMP. IN THE WATER COLUMN
JUN. 28	0800	69.00	68.00	66.00	65.00	64.00	62.00	62.00	0800	64.938
.	0900	69.00	68.00	67.00	66.00	63.00	62.00	62.00	0900	65.031
.	1000	70.00	70.00	68.00	65.00	63.00	62.50	62.00	1000	65.500
.	1100	70.00	70.00	69.00	64.00	63.00	62.50	62.00	1100	65.469
.	1200	71.50	71.00	68.50	64.50	63.00	62.50	62.50	1200	65.828
.	1300	72.00	70.50	67.00	65.50	63.50	63.00	63.00	1300	66.000
.	1400	72.00	72.00	68.00	64.00	63.50	63.00	63.00	1400	66.125
.	1500	72.00	72.00	71.50	64.50	63.50	62.80	62.80	1500	66.584
.	1600	71.00	71.00	71.00	70.50	64.00	63.00	62.50	1600	67.313
.	1700	70.00	70.00	70.00	69.80	64.00	63.00	62.50	1700	66.828
.	1800	69.50	69.00	69.00	69.00	64.00	62.50	62.20	1800	66.253
.	1900	69.00	68.50	68.50	68.50	63.00	62.50	62.20	1900	65.800
.	2000	68.50	68.00	67.50	65.00	62.50	62.00	62.00	2000	64.797
.	2100	68.50	68.00	68.00	64.60	62.00	61.80	61.80	2100	64.647
.	2200	68.50	68.20	68.00	67.50	63.00	62.00	61.80	2200	65.356
.	2300	70.50	69.50	68.50	67.00	62.50	62.00	62.00	2300	65.656
.	2400	70.20	68.50	68.00	64.00	62.50	62.00	62.00	2400	64.941
JUN. 29	0100	69.50	69.00	67.00	64.00	63.00	62.00	62.00	0100	64.922
.	0200	71.00	69.00	67.00	65.00	63.00	62.50	0.0	0200	66.019
.	0300	71.50	69.00	65.50	65.00	62.50	62.50	0.0	0300	65.731
.	0400	71.50	69.00	67.00	65.50	64.00	62.50	62.50	0400	65.672
.	0500	70.50	69.00	68.00	65.00	64.50	64.50	64.00	0500	66.234
.	0600	69.50	68.00	67.00	66.50	65.50	65.00	63.50	0600	66.328
.	0700	69.50	67.50	67.00	67.00	65.50	64.00	63.50	0700	66.141

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

TEMPERATURES RECORDED AT VARIOUS DEPTHS DURING SAMPLING DAY NO. 1 - (TEMP. IN DEG. C.)

DEPTH IN METERS ->		0.0	3.00	5.00	7.00	10.00	13.00	16.00		WEIGHED MEAN TEMP. IN THE WATER COLUMN
DAY	TIME								TIME	
JUN. 28	0800	20.56	20.00	18.89	18.33	17.78	16.67	16.67	0800	18.299
.	0900	20.56	20.00	19.44	18.89	17.22	16.67	16.67	0900	18.351
.	1000	21.11	21.11	20.00	18.33	17.22	16.94	16.67	1000	18.611
.	1100	21.11	21.11	20.56	17.78	17.22	16.94	16.67	1100	18.594
.	1200	21.94	21.67	20.28	18.06	17.22	16.94	16.94	1200	18.793
.	1300	22.22	21.39	19.44	18.61	17.50	17.22	17.22	1300	18.889
.	1400	22.22	22.22	20.00	17.78	17.50	17.22	17.22	1400	18.958
.	1500	22.22	22.22	21.94	18.06	17.50	17.11	17.11	1500	19.214
.	1600	21.67	21.67	21.67	21.39	17.78	17.22	16.94	1600	19.618
.	1700	21.11	21.11	21.11	21.00	17.78	17.22	16.94	1700	19.349
.	1800	20.83	20.56	20.56	20.56	17.78	16.94	16.78	1800	19.029
.	1900	20.56	20.28	20.28	20.28	17.22	16.94	16.78	1900	18.778
.	2000	20.28	20.00	19.72	18.33	16.94	16.67	16.67	2000	18.220
.	2100	20.28	20.00	20.00	18.11	16.67	16.56	16.56	2100	18.137
.	2200	20.28	20.11	20.00	19.72	17.22	16.67	16.56	2200	18.531
.	2300	21.39	20.83	20.28	19.44	16.94	16.67	16.67	2300	18.698
.	2400	21.22	20.28	20.00	17.78	16.94	16.67	16.67	2400	18.300
JUN. 29	0100	20.83	20.56	19.44	17.78	17.22	16.67	16.67	0100	18.290
.	0200	21.67	20.56	19.44	18.33	17.22	16.94	0.0	0200	18.900
.	0300	21.94	20.56	18.61	18.33	16.94	16.94	0.0	0300	18.739
.	0400	21.94	20.56	19.44	18.61	17.78	16.94	16.94	0400	18.707
.	0500	21.39	20.56	20.00	18.33	18.06	18.06	17.78	0500	19.019
.	0600	20.83	20.00	19.44	19.17	18.61	18.33	17.50	0600	19.071
.	0700	20.83	19.72	19.44	19.44	18.61	17.78	17.50	0700	18.967

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

TEMPERATURES RECORDED AT VARIOUS DEPTHS DURING SAMPLING DAY NO. 2 - (TEMP. IN DEG. F.)

DEPTH IN METERS ->		0.0	3.00	5.00	7.00	10.00	13.00	16.00		WEIGHED MEAN TEMP. IN THE WATER COLUMN
DAY	TIME								TIME	
JUL. 1	0800	69.50	67.50	67.20	65.50	64.00	64.00	64.00	0800	65.697
.	0900	69.50	68.00	66.00	64.50	64.00	64.00	63.50	0900	65.422
.	1000	68.50	67.80	67.20	64.30	63.80	63.80	63.80	1000	65.369
.	1100	68.00	67.50	65.50	64.80	64.20	63.80	63.20	1100	65.159
.	1200	68.80	67.80	65.20	65.00	64.20	63.50	63.20	1200	65.219
.	1300	68.80	68.00	67.00	66.20	64.50	63.80	63.50	1300	65.803
.	1400	69.80	69.50	68.50	66.20	64.00	64.00	64.00	1400	66.309
.	1500	70.50	69.00	68.20	66.20	64.50	64.20	64.20	1500	66.409
.	1600	72.00	71.80	66.80	65.00	64.20	64.00	0.0	1600	67.092
.	1700	72.50	71.50	65.20	64.80	64.50	64.20	63.80	1700	66.356
.	1800	72.20	71.50	70.20	64.80	64.60	64.20	63.50	1800	66.944
.	1900	70.80	70.20	70.00	66.20	64.50	64.20	63.80	1900	66.812
.	2000	69.80	69.80	69.80	65.00	64.00	64.00	63.80	2000	66.312
.	2100	69.20	69.00	68.80	68.80	64.00	63.80	63.80	2100	66.562
.	2200	69.50	68.80	68.00	68.00	63.90	63.80	63.80	2200	66.316
.	2300	68.80	67.60	67.50	66.80	63.80	63.50	63.50	2300	65.709
.	2400	68.30	67.80	67.00	67.00	63.80	63.20	63.20	2400	65.578
JUL. 2	0100	68.20	67.50	67.00	66.00	64.00	63.60	63.20	0100	65.478
.	0200	70.50	67.50	67.00	65.00	63.80	63.60	0.0	0200	65.985
.	0300	71.00	68.00	67.20	65.50	64.00	63.80	63.50	0300	65.831
.	0400	71.20	67.90	66.80	64.20	64.00	64.00	63.80	0400	65.647
.	0500	71.50	68.80	65.00	64.90	64.50	64.00	64.00	0500	65.812
.	0600	71.50	67.60	66.50	65.00	63.80	63.80	0.0	0600	66.065
.	0700	71.00	68.80	67.00	64.80	63.80	63.60	63.60	0700	65.756

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

TEMPERATURES RECORDED AT VARIOUS DEPTHS DURING SAMPLING DAY NO. 2 - (TEMP. IN DEG. C.)

DEPTH IN METERS ->		0.0	3.00	5.00	7.00	10.00	13.00	16.00		WEIGHED MEAN TEMP. IN THE WATER COLUMN
DAY	TIME								TIME	
JUL. 1	0800	20.83	19.72	19.56	18.61	17.78	17.78	17.78	0800	18.720
.	0900	20.83	20.00	18.89	18.06	17.78	17.78	17.50	0900	18.568
.	1000	20.28	19.89	19.56	17.94	17.67	17.67	17.67	1000	18.538
.	1100	20.00	19.72	18.61	18.22	17.89	17.67	17.33	1100	18.422
.	1200	20.44	19.89	18.44	18.33	17.89	17.50	17.33	1200	18.455
.	1300	20.44	20.00	19.44	19.00	18.06	17.67	17.50	1300	18.779
.	1400	21.00	20.83	20.28	19.00	17.78	17.78	17.78	1400	19.061
.	1500	21.39	20.56	20.11	19.00	18.06	17.89	17.89	1500	19.116
.	1600	22.22	22.11	19.33	18.33	17.89	17.78	0.0	1600	19.496
.	1700	22.50	21.94	18.44	18.22	18.06	17.89	17.67	1700	19.087
.	1800	22.33	21.94	21.22	18.22	18.11	17.89	17.50	1800	19.413
.	1900	21.56	21.22	21.11	19.00	18.06	17.89	17.67	1900	19.340
.	2000	21.00	21.00	21.00	18.33	17.78	17.78	17.67	2000	19.062
.	2100	20.67	20.56	20.44	20.44	17.78	17.67	17.67	2100	19.201
.	2200	20.83	20.44	20.00	20.00	17.72	17.67	17.67	2200	19.064
.	2300	20.44	19.78	19.72	19.33	17.67	17.50	17.50	2300	18.727
.	2400	20.17	19.89	19.44	19.44	17.67	17.33	17.33	2400	18.654
JUL. 2	0100	20.11	19.72	19.44	18.89	17.78	17.56	17.33	0100	18.599
.	0200	21.39	19.72	19.44	18.33	17.67	17.56	0.0	0200	18.880
.	0300	21.67	20.00	19.56	18.61	17.78	17.67	17.50	0300	18.795
.	0400	21.78	19.94	19.33	17.89	17.78	17.78	17.67	0400	18.693
.	0500	21.94	20.44	18.33	18.28	18.06	17.78	17.78	0500	18.785
.	0600	21.94	19.78	19.17	18.33	17.67	17.67	0.0	0600	18.925
.	0700	21.67	20.44	19.44	18.22	17.67	17.56	17.56	0700	18.753

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

TEMPERATURES RECORDED AT VARIOUS DEPTHS DURING SAMPLING DAY NO. 3 - (TEMP. IN DEG. F.)

DEPTH IN METERS -> DAY	TIME	0.0	3.00	5.00	7.00	10.00	13.00	16.00	TIME	WEIGHED MEAN TEMP. IN THE WATER COLUMN
JUL. 7	0800	72.00	72.00	69.20	67.50	66.10	65.50	0.0	0800	68.592
.	0900	72.30	72.30	69.70	68.00	66.20	65.60	0.0	0900	68.892
.	1000	73.00	72.90	69.20	67.00	66.80	66.50	66.00	1000	68.534
.	1100	72.80	72.80	71.80	67.20	67.00	66.20	65.80	1100	68.819
.	1200	73.30	73.30	72.80	67.60	67.00	66.30	66.00	1200	69.169
.	1300	72.20	72.20	72.00	69.00	66.60	66.40	66.10	1300	68.966
.	1400	70.80	70.60	70.60	70.50	67.20	66.20	65.80	1400	68.691
.	1500	70.30	70.30	70.20	70.10	68.90	66.80	66.10	1500	68.944
.	1600	69.80	69.60	69.30	69.00	66.90	66.20	66.00	1600	68.006
.	1700	69.60	69.60	69.20	69.10	66.80	66.30	66.20	1700	68.009
.	1800	69.60	69.40	69.00	68.80	67.50	66.20	65.80	1800	67.981
.	1900	69.50	69.30	69.10	69.10	66.00	65.80	0.0	1900	68.088
.	2000	70.20	70.00	69.30	69.10	66.70	66.20	0.0	2000	68.542
.	2100	70.50	70.00	69.80	69.20	68.00	66.50	0.0	2100	69.008
.	2200	71.00	71.00	70.20	69.00	68.00	66.30	0.0	2200	69.258
.	2300	71.00	71.00	69.20	68.50	68.20	67.90	66.50	2300	68.856
.	2400	71.00	71.00	70.50	69.00	67.80	67.20	66.50	2400	68.891
JUL. 8	0100	70.30	70.20	70.20	68.20	67.00	66.00	0.0	0100	68.604
.	0200	70.00	69.80	69.80	68.80	67.50	67.20	66.80	0200	68.462
.	0300	69.50	69.30	69.30	69.30	69.00	67.00	66.80	0300	68.597
.	0400	68.50	68.50	68.50	68.50	68.40	68.20	67.50	0400	68.331
.	0500	68.20	68.10	68.10	68.00	68.00	68.00	68.00	0500	68.047
.	0600	68.50	68.20	68.20	67.80	67.50	67.30	66.80	0600	67.734
.	0700	68.50	68.50	68.30	68.30	67.20	67.20	67.00	0700	67.816

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

TEMPERATURES RECORDED AT VARIOUS DEPTHS DURING SAMPLING DAY NO. 3 - (TEMP. IN DEG. C.)

DEPTH IN METERS ->		0.0	3.00	5.00	7.00	10.00	13.00	16.00		WEIGHED MEAN TEMP. IN THE WATER COLUMN
DAY	TIME								TIME	
JUL. 7	0800	22.22	22.22	20.67	19.72	18.94	18.61	0.0	0800	20.329
.	0900	22.39	22.39	20.94	20.00	19.00	18.67	0.0	0900	20.496
.	1000	22.78	22.72	20.67	19.44	19.33	19.17	18.89	1000	20.297
.	1100	22.67	22.67	22.11	19.56	19.44	19.00	18.78	1100	20.455
.	1200	22.94	22.94	22.67	19.78	19.44	19.06	18.89	1200	20.649
.	1300	22.33	22.33	22.22	20.56	19.22	19.11	18.94	1300	20.536
.	1400	21.56	21.44	21.44	21.39	19.56	19.00	18.78	1400	20.384
.	1500	21.28	21.28	21.22	21.17	20.50	19.33	18.94	1500	20.524
.	1600	21.00	20.89	20.72	20.56	19.39	19.00	18.89	1600	20.003
.	1700	20.89	20.89	20.67	20.61	19.33	19.06	19.00	1700	20.005
.	1800	20.89	20.78	20.56	20.44	19.72	19.00	18.78	1800	19.990
.	1900	20.83	20.72	20.61	20.61	18.89	18.78	0.0	1900	20.049
.	2000	21.22	21.11	20.72	20.61	19.28	19.00	0.0	2000	20.301
.	2100	21.39	21.11	21.00	20.67	20.00	19.17	0.0	2100	20.560
.	2200	21.67	21.67	21.22	20.56	20.00	19.06	0.0	2200	20.699
.	2300	21.67	21.67	20.67	20.28	20.11	19.94	19.17	2300	20.476
.	2400	21.67	21.67	21.39	20.56	19.89	19.56	19.17	2400	20.495
JUL. 8	0100	21.28	21.22	21.22	20.11	19.44	18.89	0.0	0100	20.335
.	0200	21.11	21.00	21.00	20.44	19.72	19.56	19.33	0200	20.257
.	0300	20.83	20.72	20.72	20.72	20.56	19.44	19.33	0300	20.332
.	0400	20.28	20.28	20.28	20.28	20.22	20.11	19.72	0400	20.184
.	0500	20.11	20.06	20.06	20.00	20.00	20.00	20.00	0500	20.026
.	0600	20.28	20.11	20.11	19.89	19.72	19.61	19.33	0600	19.852
.	0700	20.28	20.28	20.17	20.17	19.56	19.56	19.44	0700	19.898

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 1 - HOURLY TEMPERATURES IN DEG. C.

TIME	SURFACE	BOTTOM	W.COL. MEAN
0800	20.56	16.67	18.30
0900	20.56	16.67	18.35
1000	21.11	16.67	18.61
1100	21.11	16.67	18.59
1200	21.94	16.94	18.79
1300	22.22	17.22	18.89
1400	22.22	17.22	18.96
1500	22.22	17.11	19.21
1600	21.67	16.94	19.62
1700	21.11	16.94	19.35
1800	20.83	16.78	19.03
1900	20.56	16.78	18.78
2000	20.28	16.67	18.22
2100	20.28	16.56	18.14
2200	20.28	16.56	18.53
2300	21.39	16.67	18.70
2400	21.22	16.67	18.30
0100	20.83	16.67	18.29
0200	21.67	16.94	18.90
0300	21.94	16.94	18.74
0400	21.94	16.94	18.71
0500	21.39	17.78	19.02
0600	20.83	17.50	19.07
0700	20.83	17.50	18.97

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 2 - HOURLY TEMPERATURES IN DEG. C.

TIME	SURFACE	BOTTOM	W.COL. MEAN
0800	20.83	17.78	18.72
0900	20.83	17.50	18.57
1000	20.28	17.67	18.54
1100	20.00	17.33	18.42
1200	20.44	17.33	18.45
1300	20.44	17.50	18.78
1400	21.00	17.78	19.06
1500	21.39	17.89	19.12
1600	22.22	17.78	19.50
1700	22.50	17.67	19.09
1800	22.33	17.50	19.41
1900	21.56	17.67	19.34
2000	21.00	17.67	19.06
2100	20.67	17.67	19.20
2200	20.83	17.67	19.06
2300	20.44	17.50	18.73
2400	20.17	17.33	18.65
0100	20.11	17.33	18.60
0200	21.39	17.56	18.88
0300	21.67	17.50	18.80
0400	21.78	17.67	18.69
0500	21.94	17.78	18.78
0600	21.94	17.67	18.93
0700	21.67	17.56	18.75

1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

SAMPLING DAY NO. 3 - HOURLY TEMPERATURES IN DEG. C.

TIME	SURFACE	BOTTOM	W.COL. MEAN
0800	22.22	18.61	20.33
0900	22.39	18.67	20.50
1000	22.78	18.89	20.30
1100	22.67	18.78	20.45
1200	22.94	18.89	20.65
1300	22.33	18.94	20.54
1400	21.56	18.78	20.38
1500	21.28	18.94	20.52
1600	21.00	18.89	20.00
1700	20.89	19.00	20.01
1800	20.89	18.78	19.99
1900	20.83	18.78	20.05
2000	21.22	19.00	20.30
2100	21.39	19.17	20.56
2200	21.67	19.06	20.70
2300	21.67	19.17	20.48
2400	21.67	19.17	20.49
0100	21.28	18.89	20.34
0200	21.11	19.33	20.26
0300	20.83	19.33	20.33
0400	20.28	19.72	20.18
0500	20.11	20.00	20.03
0600	20.28	19.33	19.85
0700	20.28	19.44	19.90

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           1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

        PLOT OF THE SURFACE WATER TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 1

TIME
       +....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+
 0800  .--------------------------------------------------*                             .
 0900  .--------------------------------------------------*                             .
 1000  .-------------------------------------------------------*                        .
 1100  .-------------------------------------------------------*                        .
 1200  .---------------------------------------------------------------*                .
 1300  .------------------------------------------------------------------*             .
 1400  .------------------------------------------------------------------*             .
 1500  .------------------------------------------------------------------*             .
 1600  .-------------------------------------------------------------*                  .
 1700  .-------------------------------------------------------*                        .
 1800  .----------------------------------------------------*                           .
 1900  .--------------------------------------------------*                             .
 2000  .-----------------------------------------------*                                .
 2100  .-----------------------------------------------*                                .
 2200  .-----------------------------------------------*                                .
 2300  .----------------------------------------------------------*                     .
 2400  .--------------------------------------------------------*                       .
 0100  .----------------------------------------------------*                           .
 0200  .-------------------------------------------------------------*                  .
 0300  .---------------------------------------------------------------*                .
 0400  .---------------------------------------------------------------*                .
 0500  .----------------------------------------------------------*                     .
 0600  .----------------------------------------------------*                           .
 0700  .----------------------------------------------------*                           .
       +....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+
SCALE ->   16.       17.       18.       19.       20.       21.       22.       23.

                               TEMPERATURE IN DEGREES CENTIGRADE
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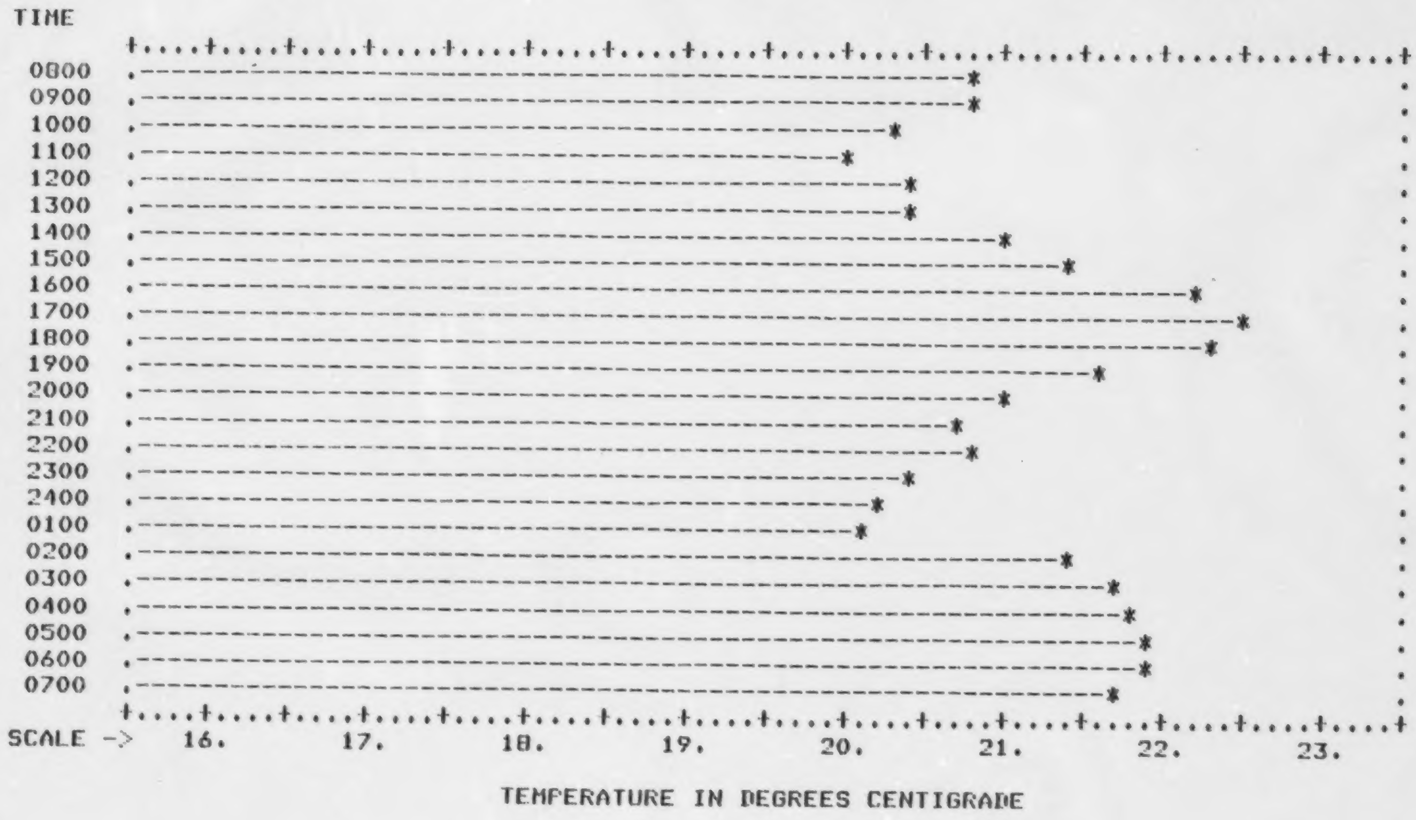
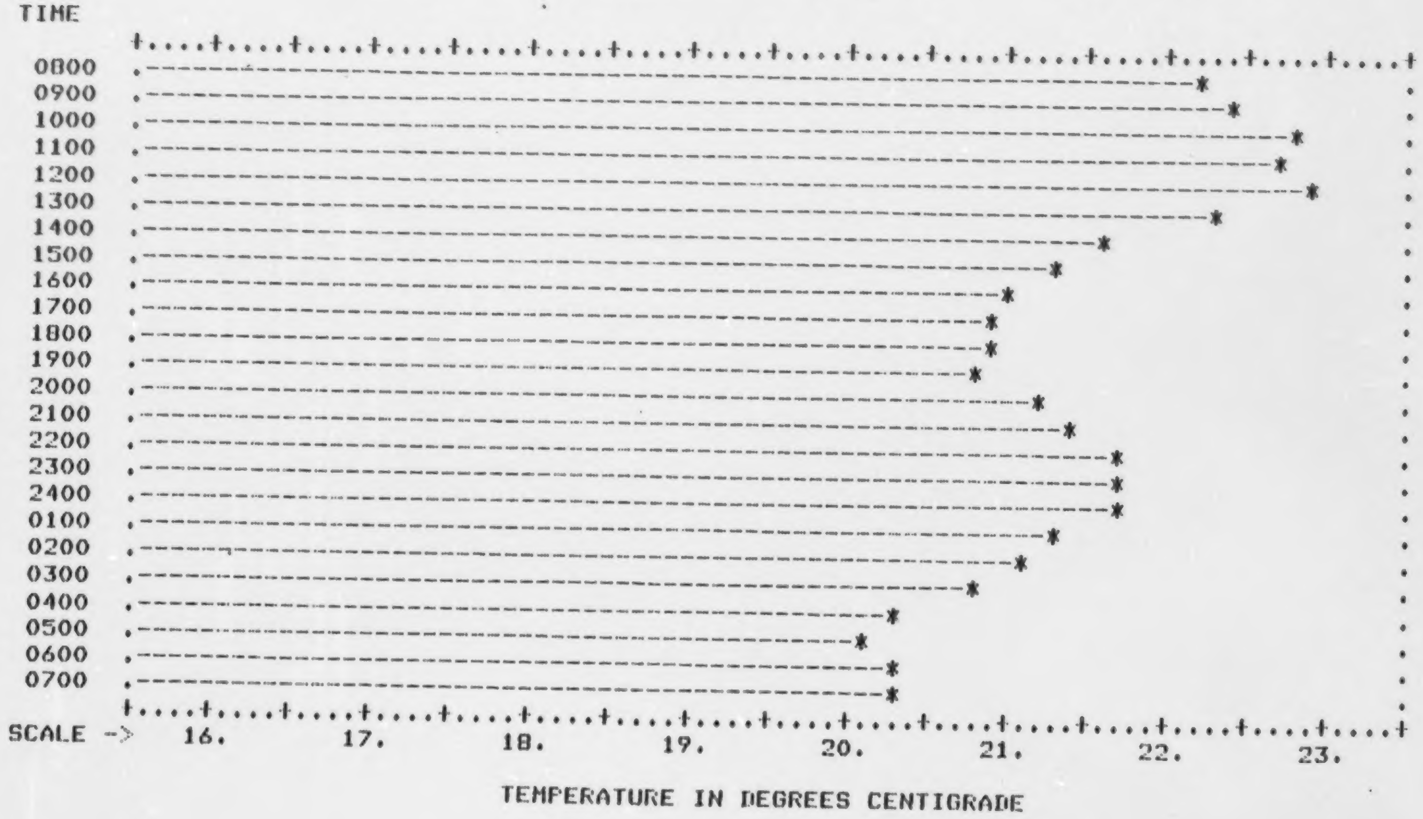
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE SURFACE WATER TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 2



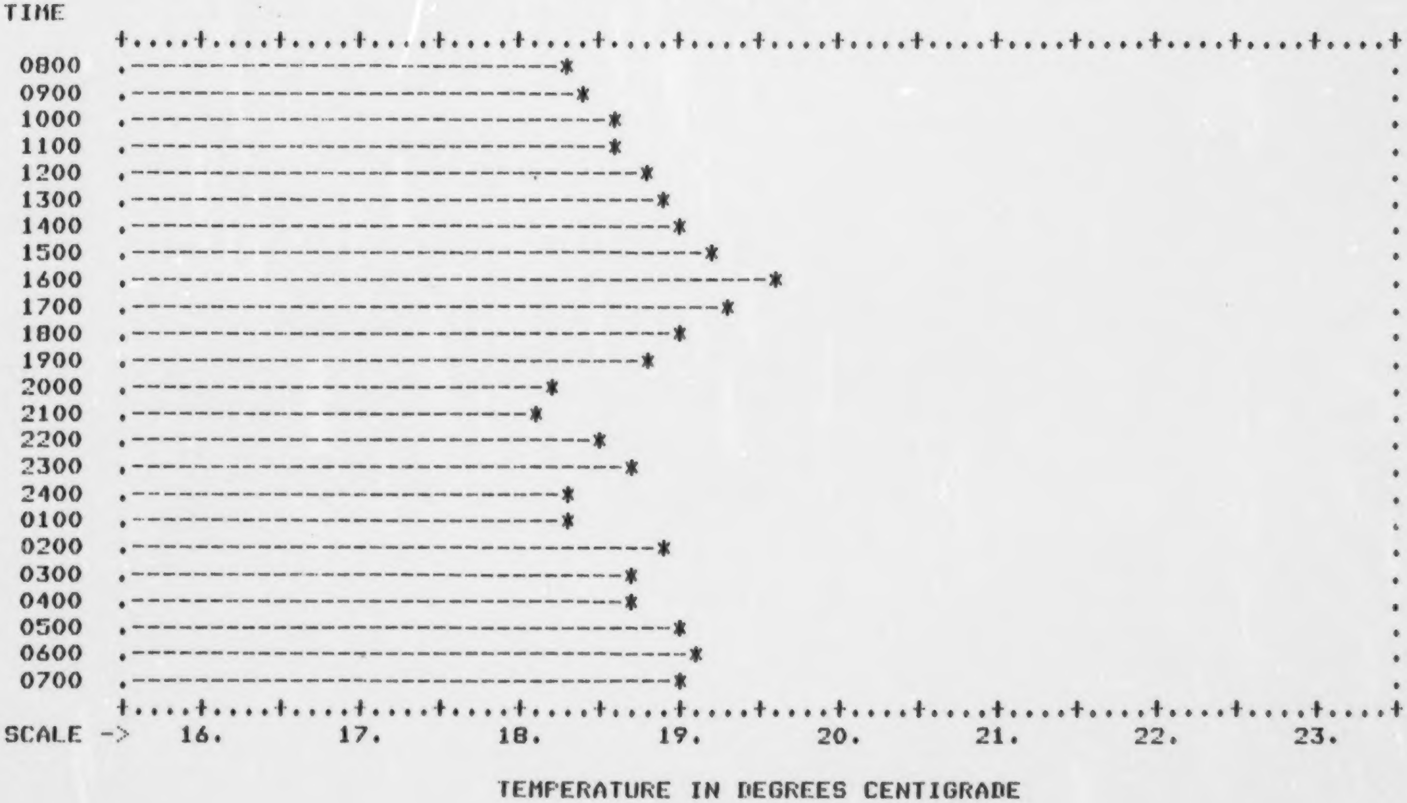
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE SURFACE WATER TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 3



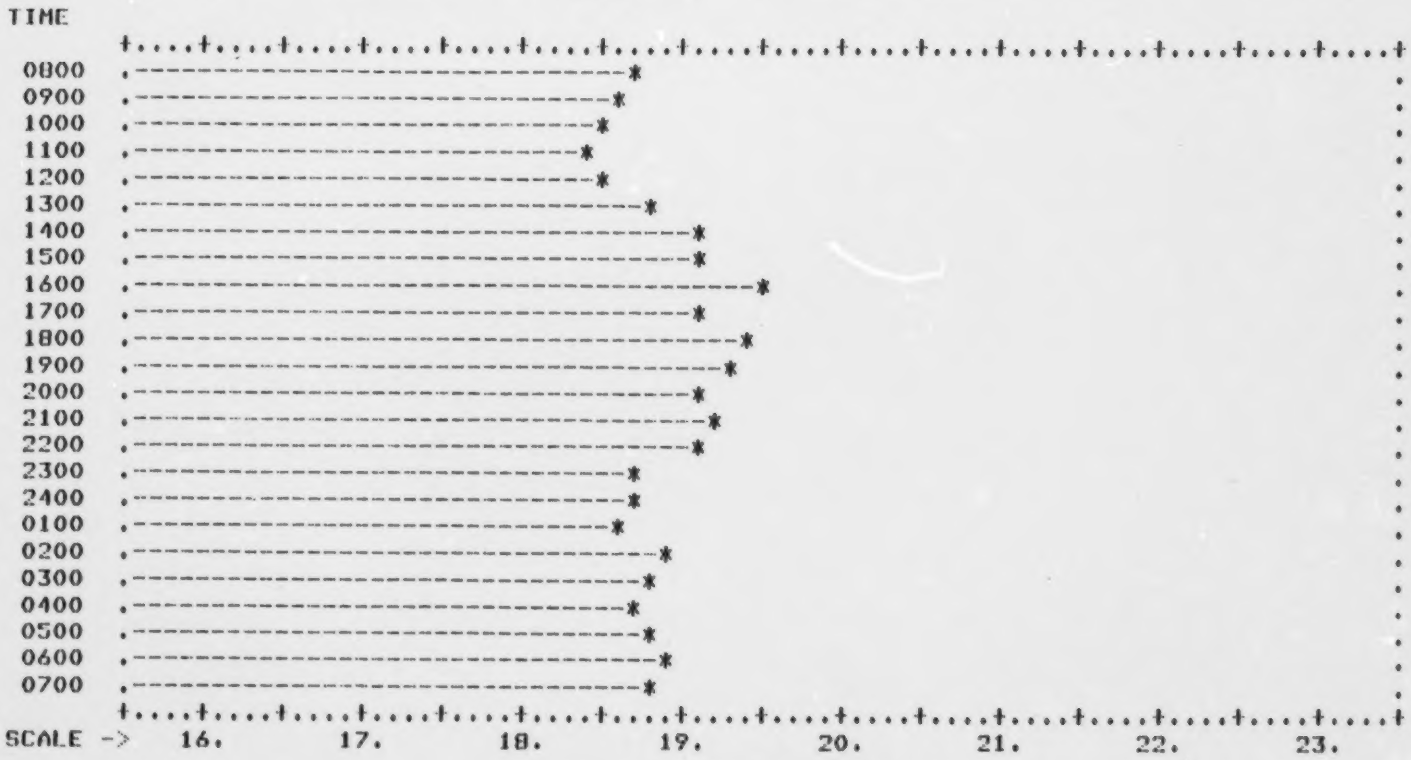
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE WATER COL. MEAN TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 1



1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

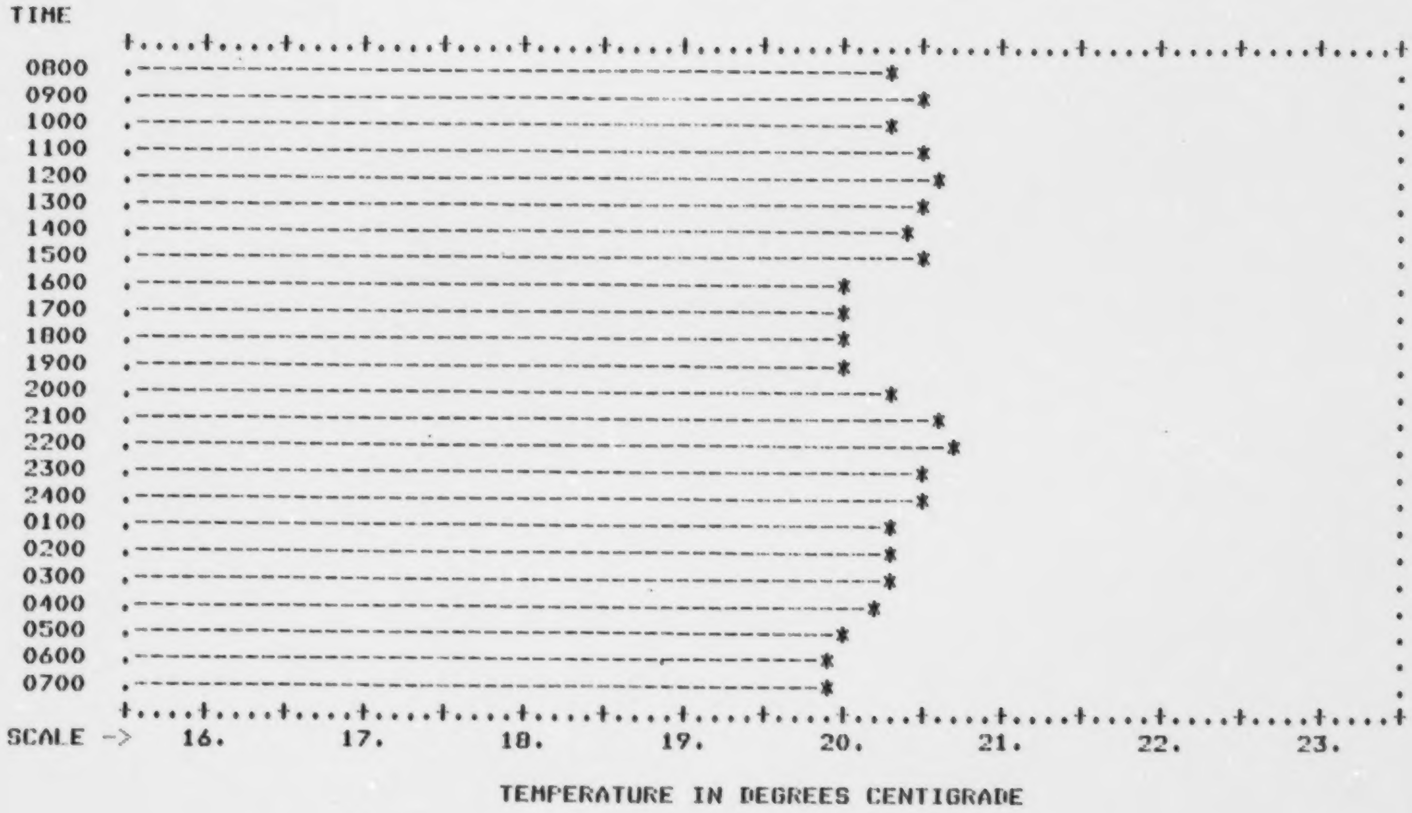
PLOT OF THE WATER COL. MEAN TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 2



TEMPERATURE IN DEGREES CENTIGRADE

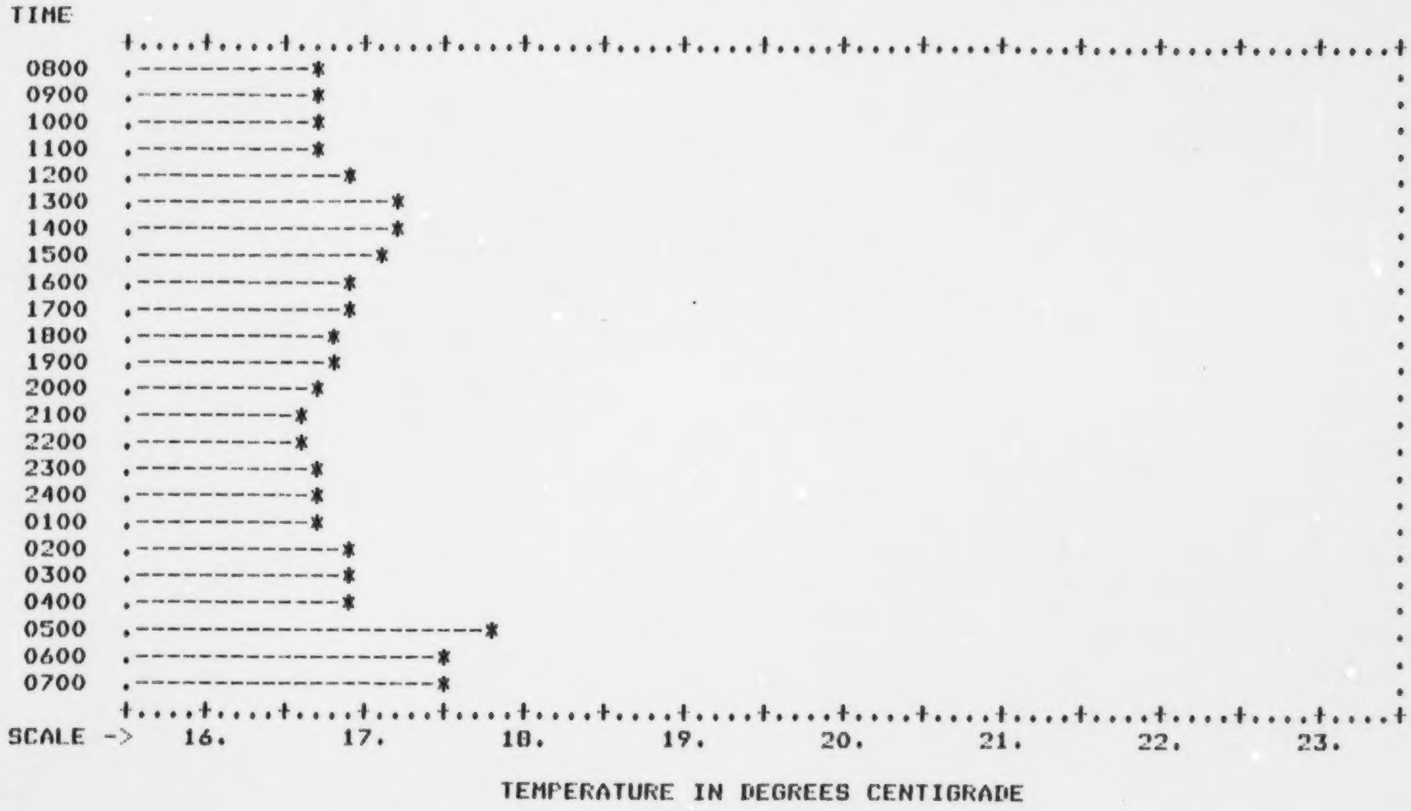
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE WATER COL. MEAN TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 3



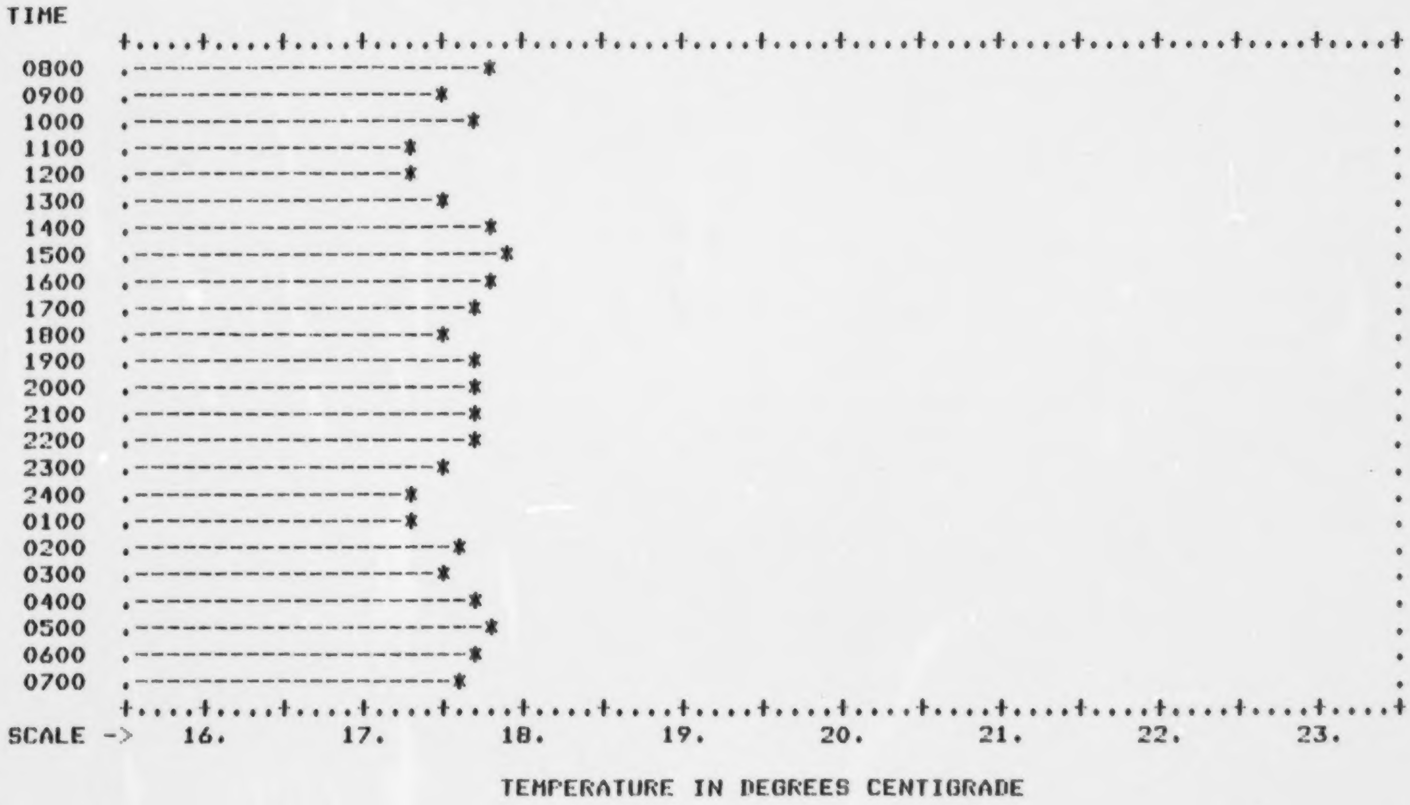
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE BOTTOM WATER TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 1



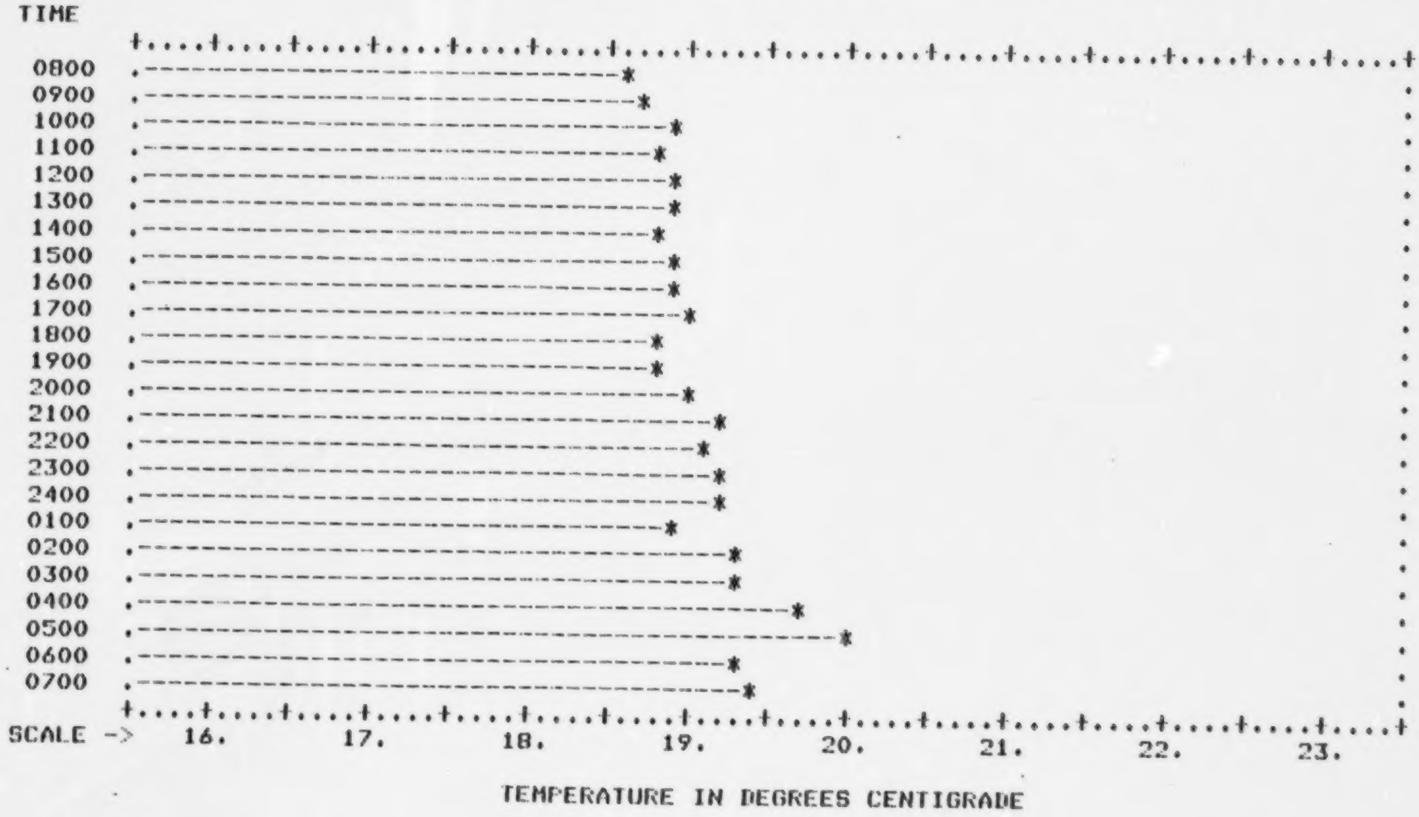
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

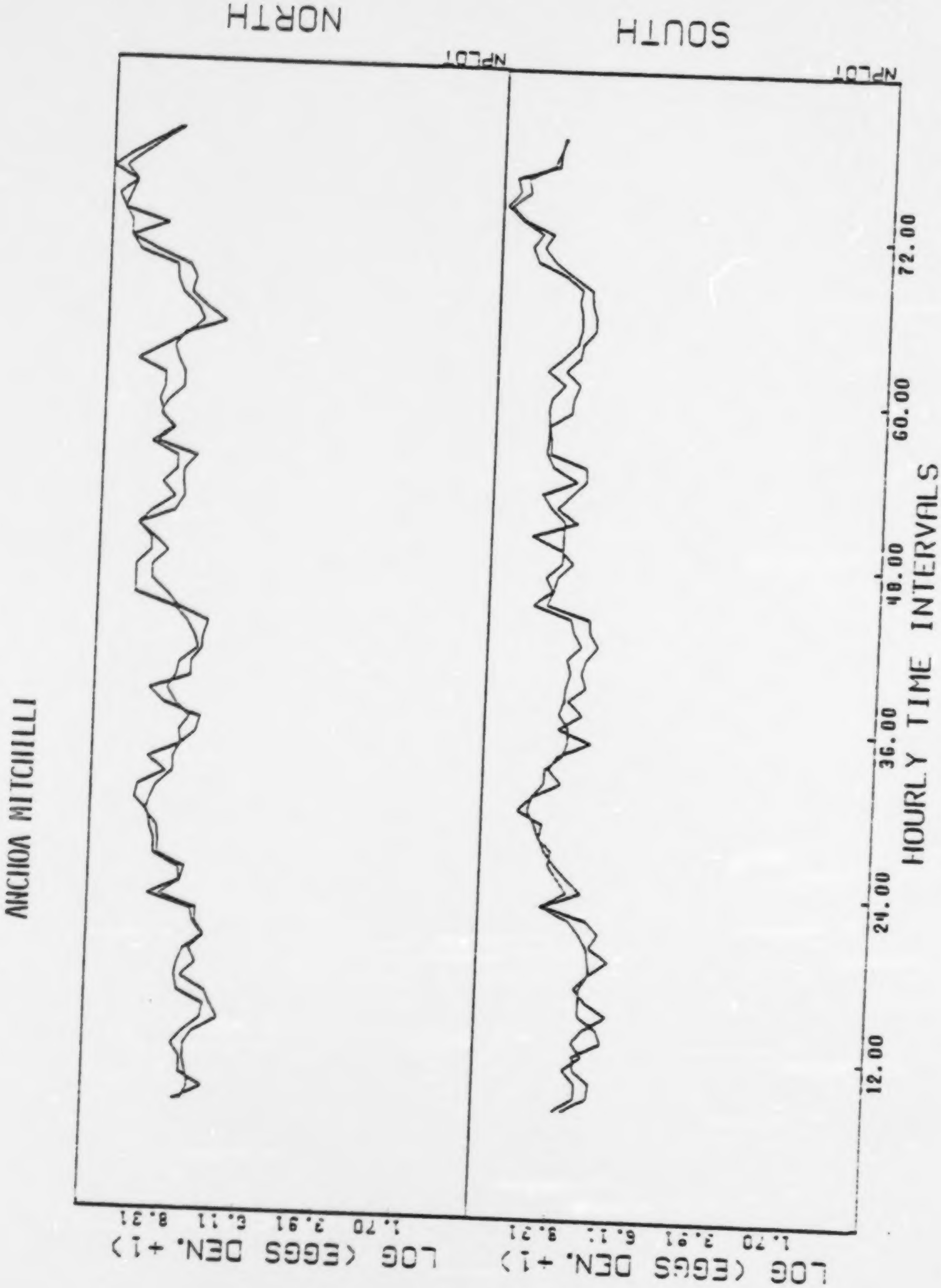
PLOT OF THE BOTTOM WATER TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 2



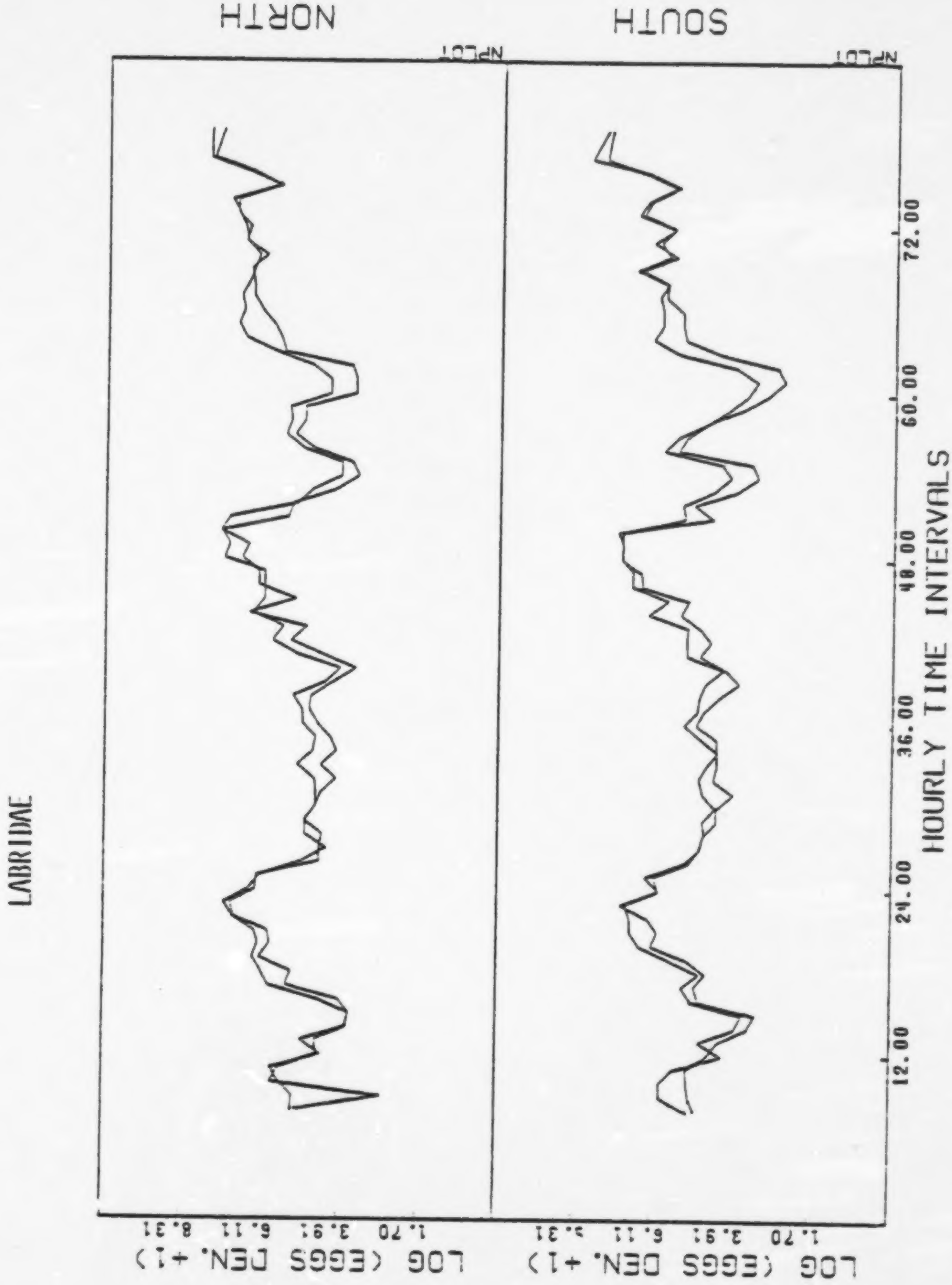
1976 - NARRAGANSETT BAY - E.P.A. ICHTHYOPLANKTON SAMPLING PROJECT

PLOT OF THE BOTTOM WATER TEMPERATURE VS. TIME DURING SAMPLING DAY NO. 3

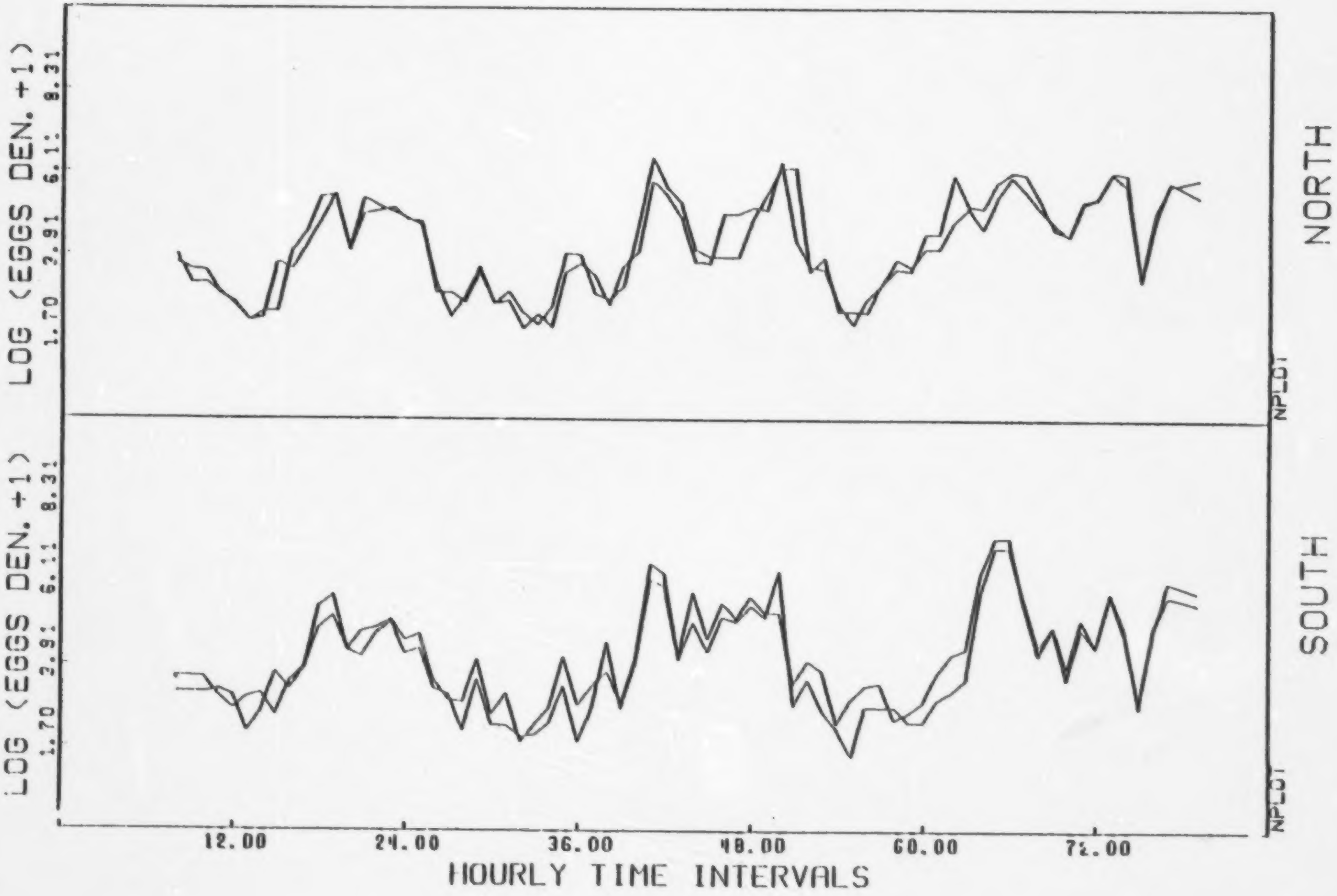



ANCHOA MITCHILLI
NORTH
SOUTH
NPLOT
NPLOT
LOG (EGGS DEN. +1)
1.70
3.91
6.11
8.31
LOG (EGGS DEN. +1)
1.70
3.91
6.11
8.31
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

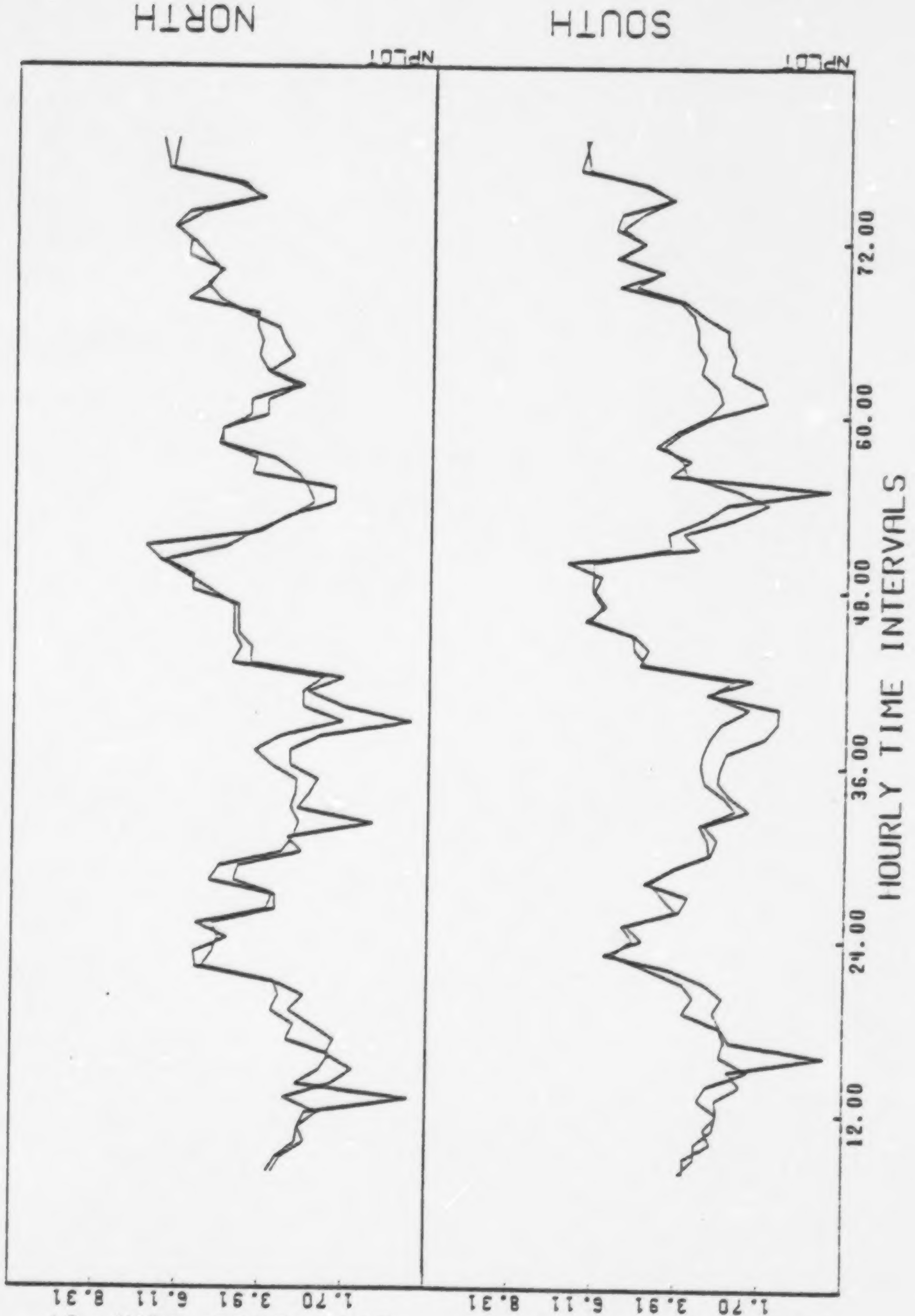
IV-1

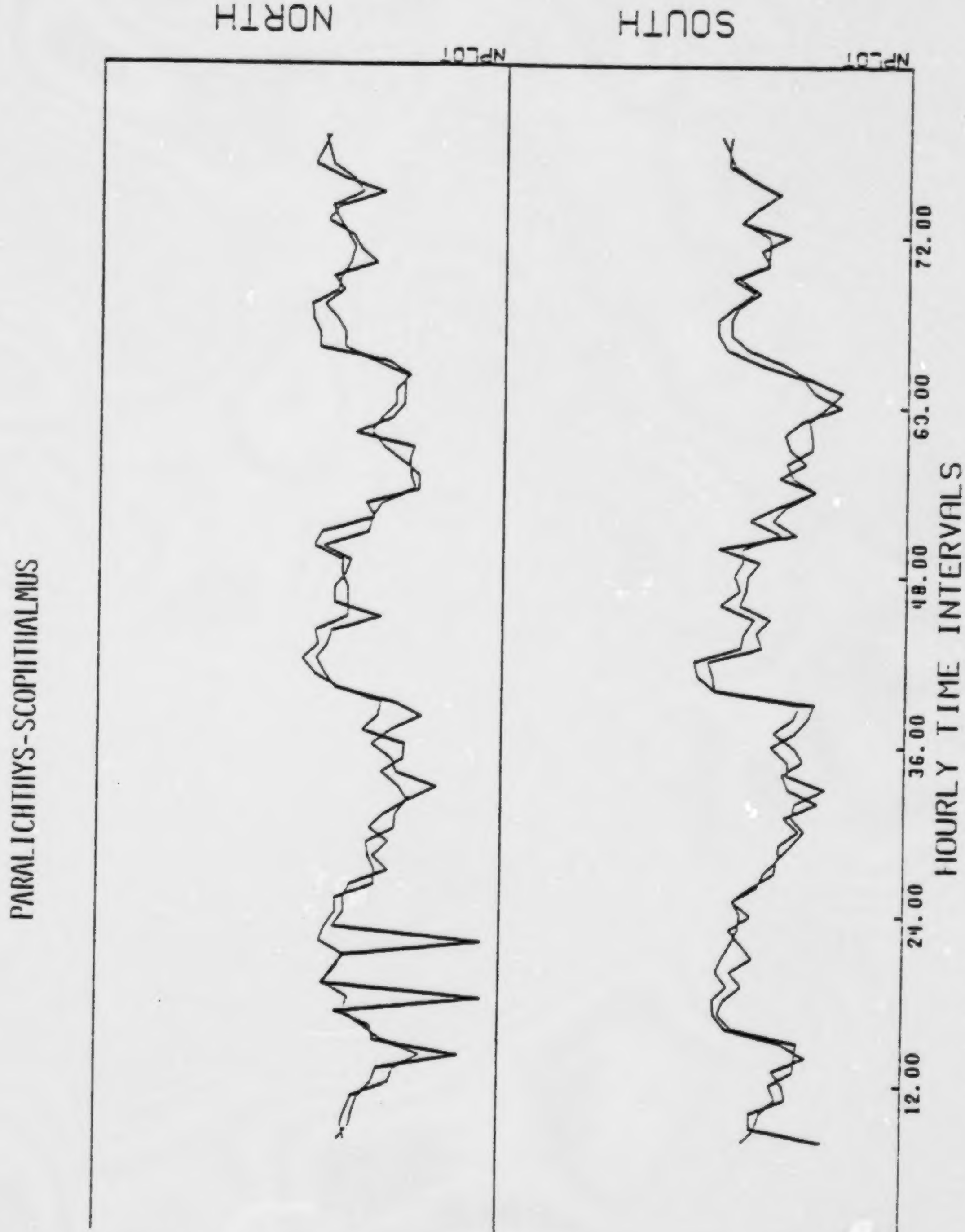

LABRIDAE
NORTH
SOUTH
NPLOT
NPLOT
LOG (EGGS DEN.+1)
1.70
3.91
6.11
8.31
LOG (EGGS DEN.+1)
1.70
3.91
6.11
8.31
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

PRIONOTUS SPP.

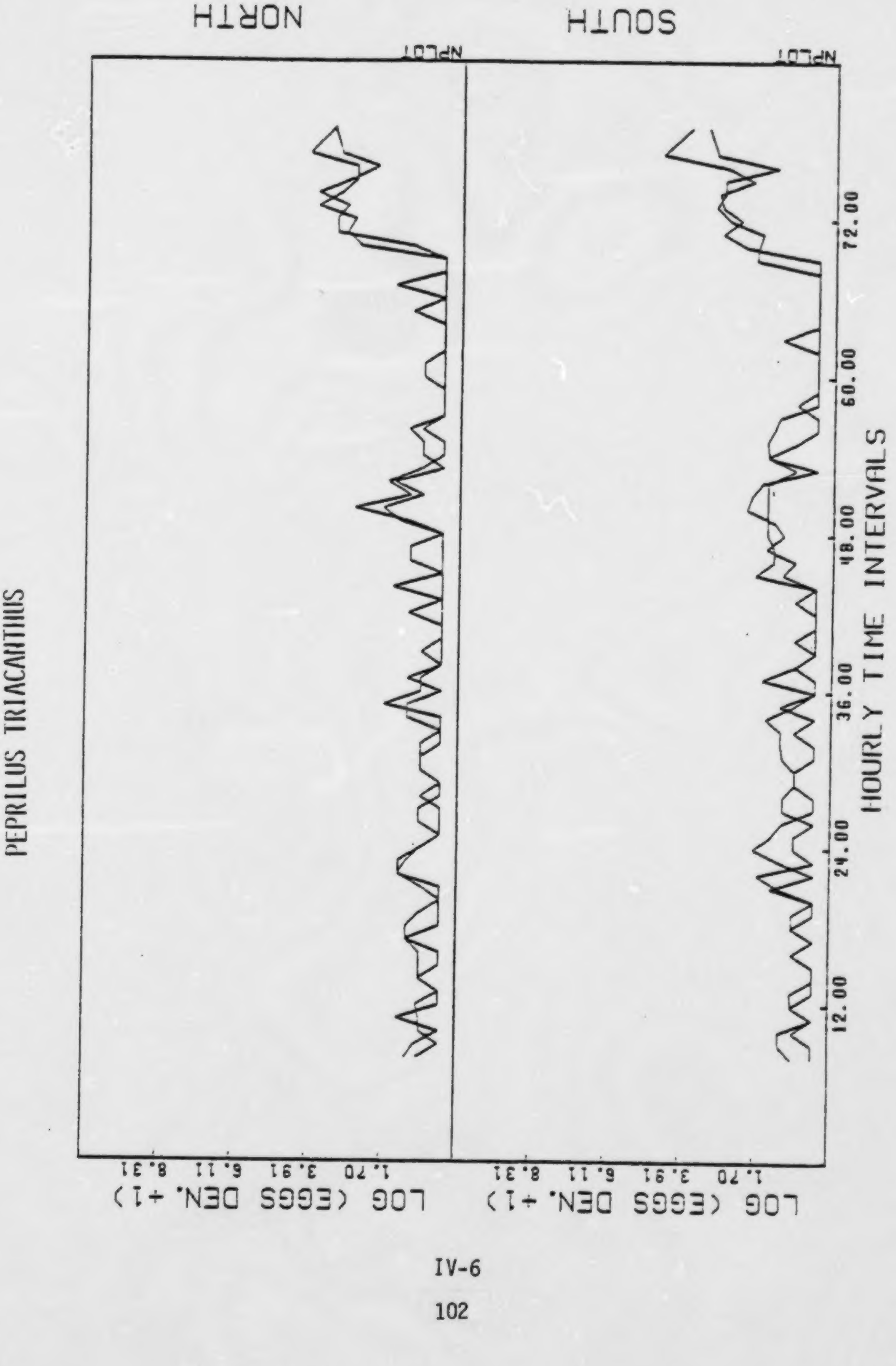


MORONE SP.

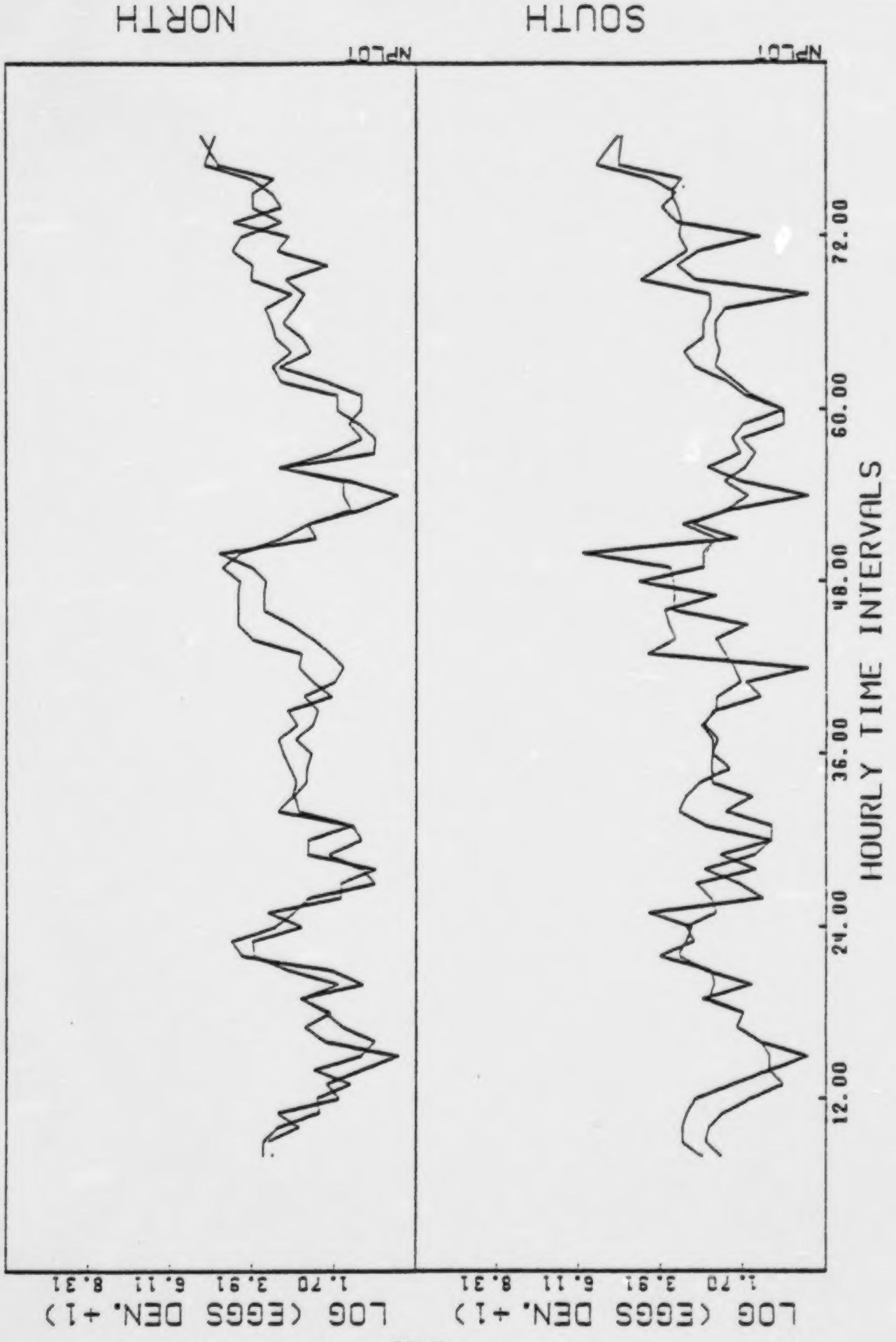

NORTH
SOUTH
NPLOT
NPLOT
LOG (EGGS DEN.+1)
1.70
3.91
6.11
8.31
LOG (EGGS DEN.+1)
1.70
3.91
6.11
8.31
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS


PARALICHTHYS-SCOPHTHALMUS
NORTH
SOUTH
NPLOT
NPLOT
LOG (EGGS DEN.+1)
1.70
3.91
6.11
8.31
LOG (EGGS DEN.+1)
1.70
3.91
6.11
8.31
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

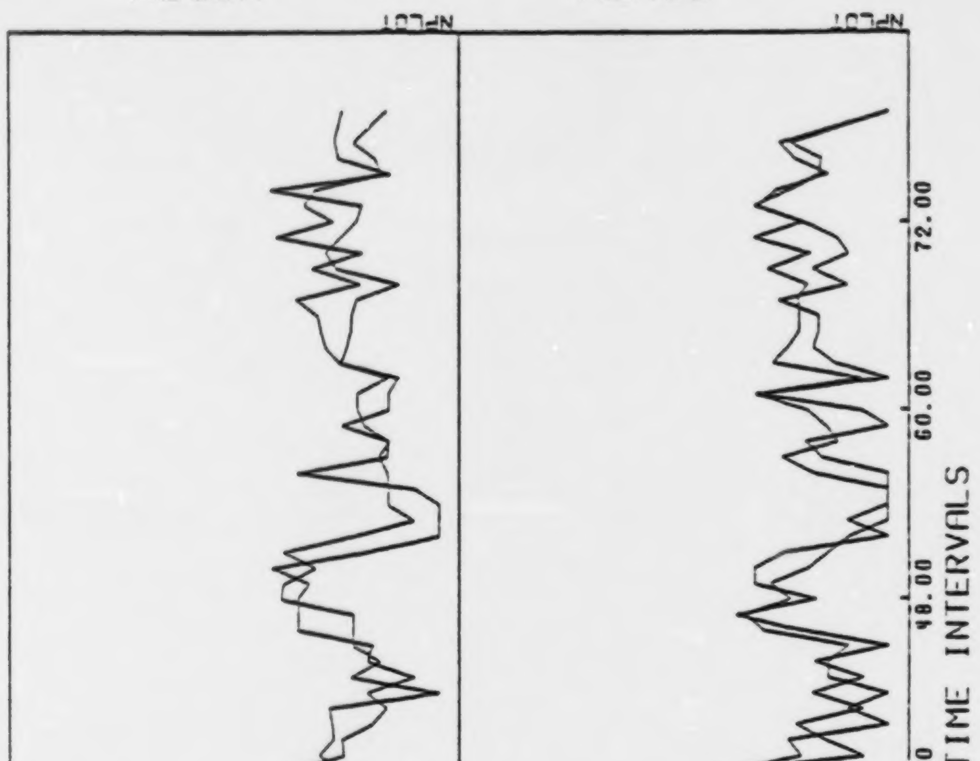
IV-5


PEPRILUS TRIACANTHUS
NORTH
SOUTH
NPLOT
NPLOT
LOG (EGGS DEN. +1)
1.70
3.91
6.11
8.31
LOG (EGGS DEN. +1)
1.70
3.91
6.11
8.31
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

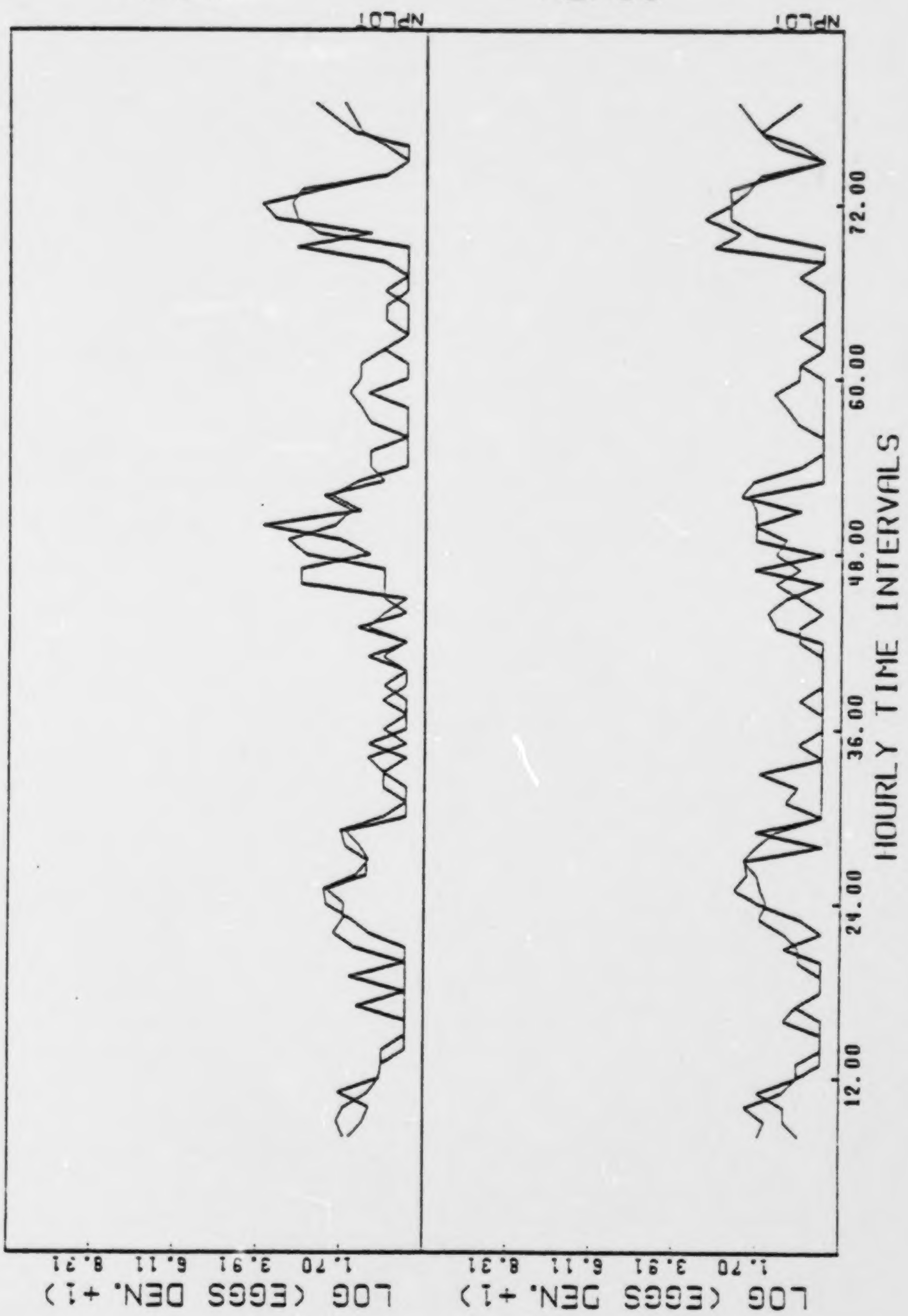
ENCHELYOPUS-UROPHYCIS-PEPRILUS



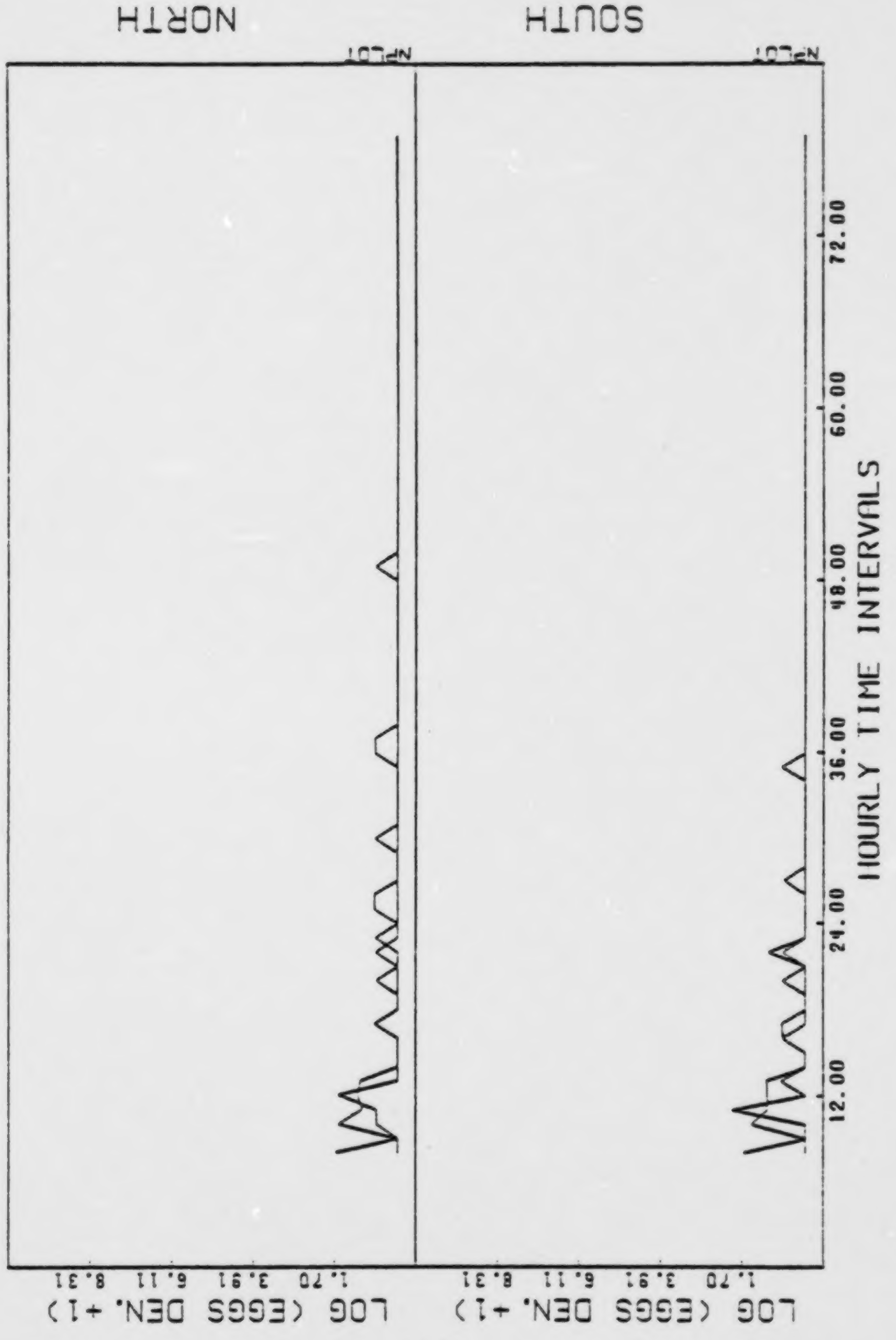
STENOTOMUS-CYNOSCION

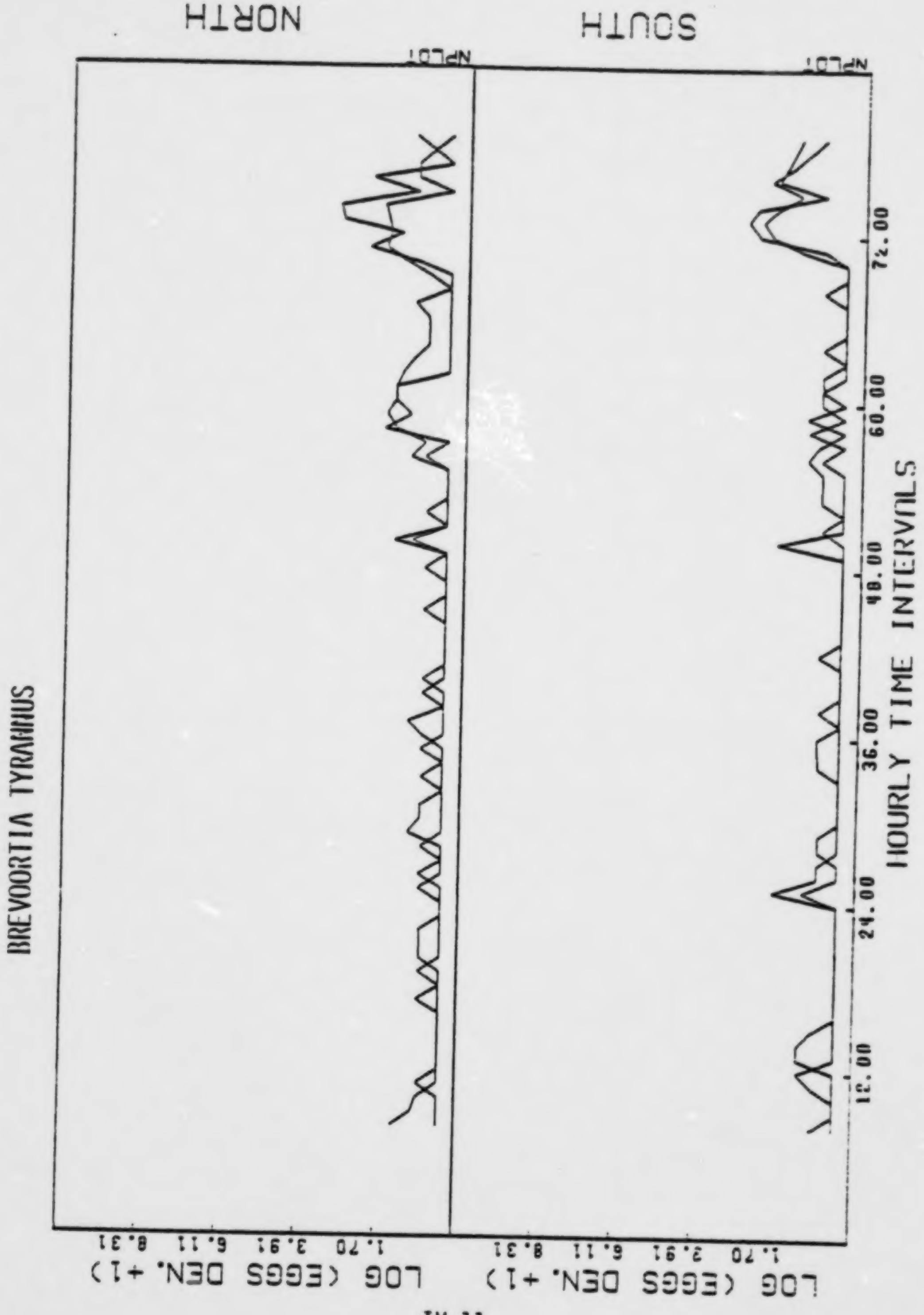


TRINECTES MACULATUS

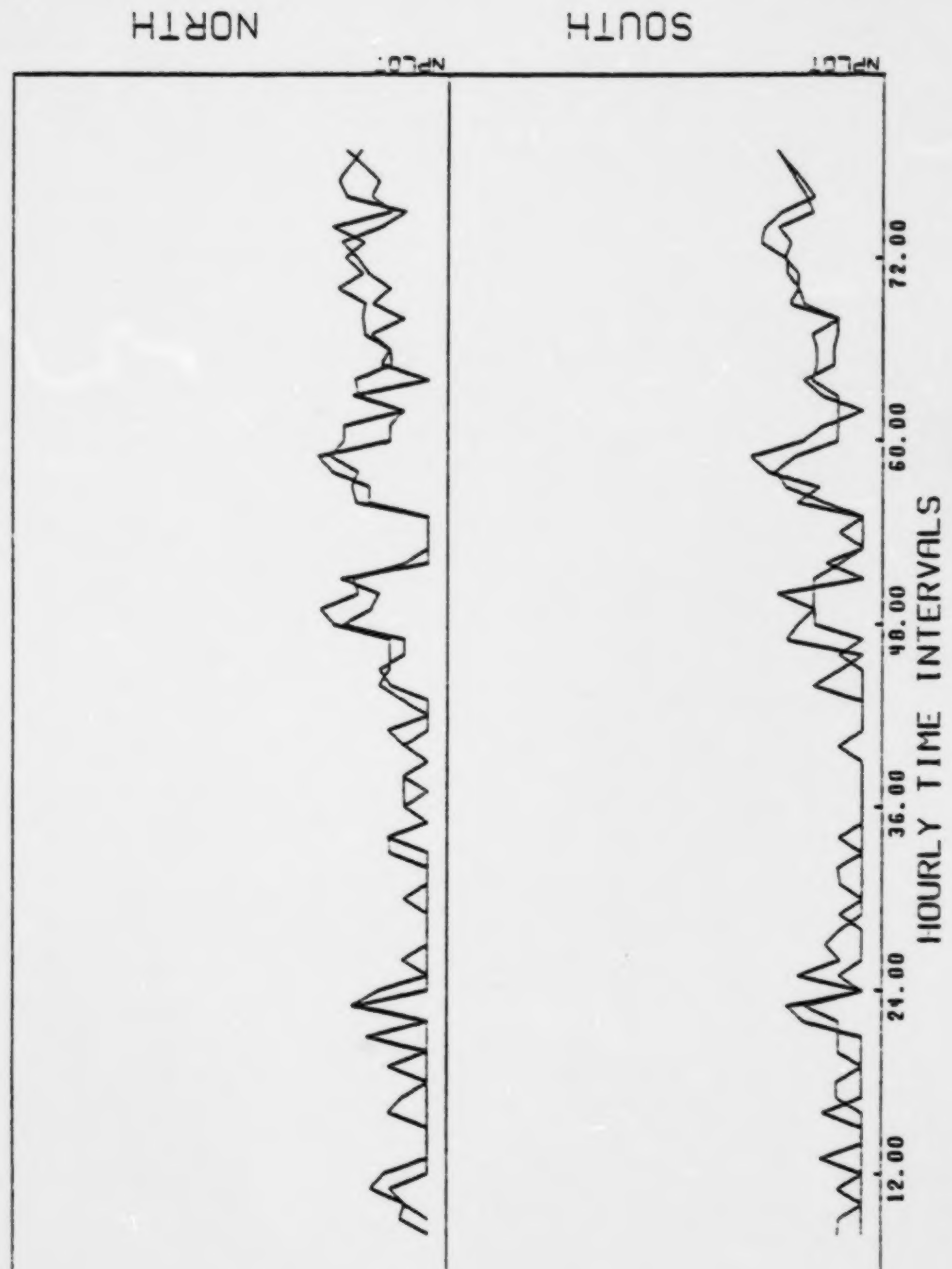


MERLUCCIUS BILINEARIS

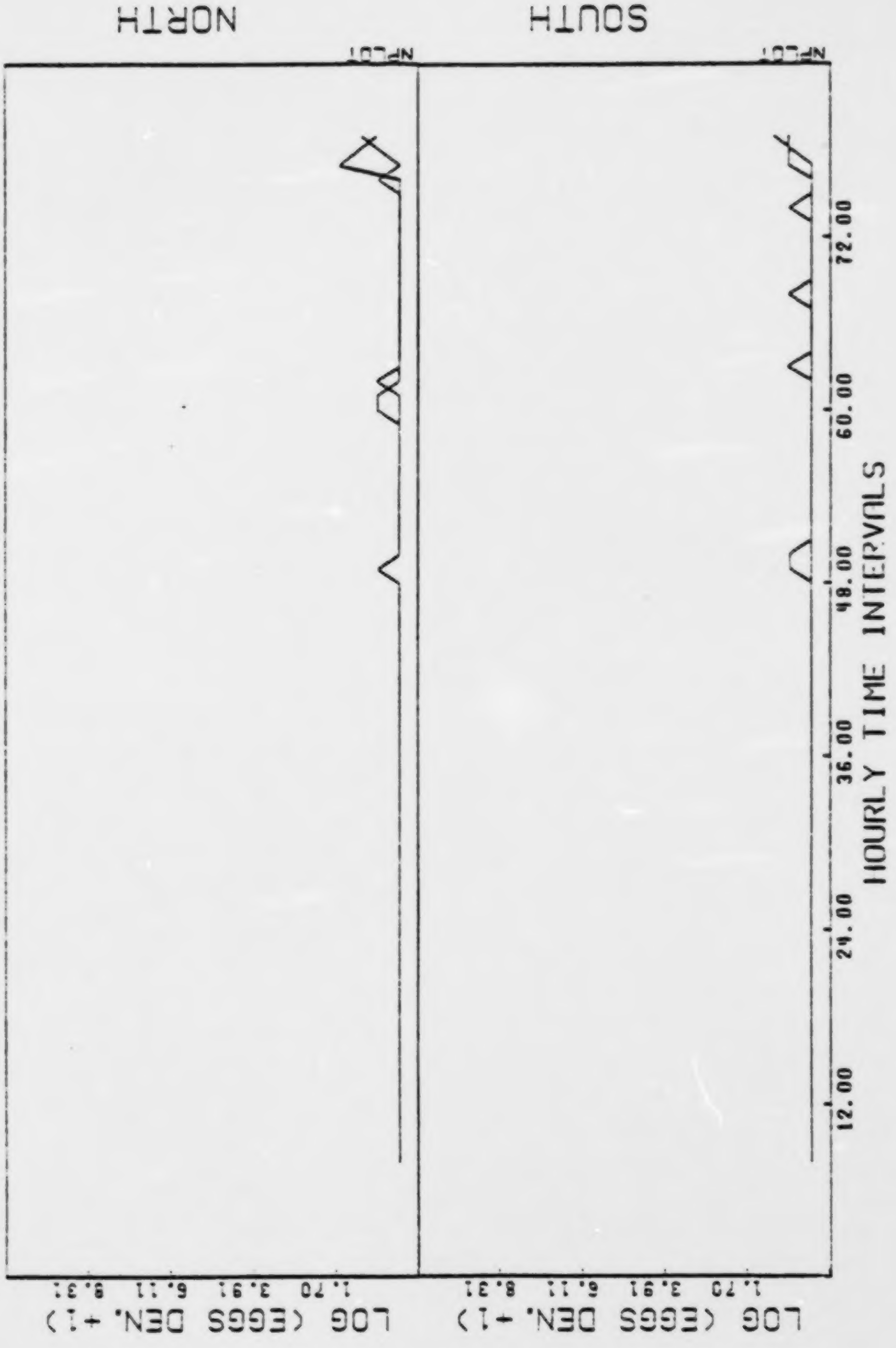


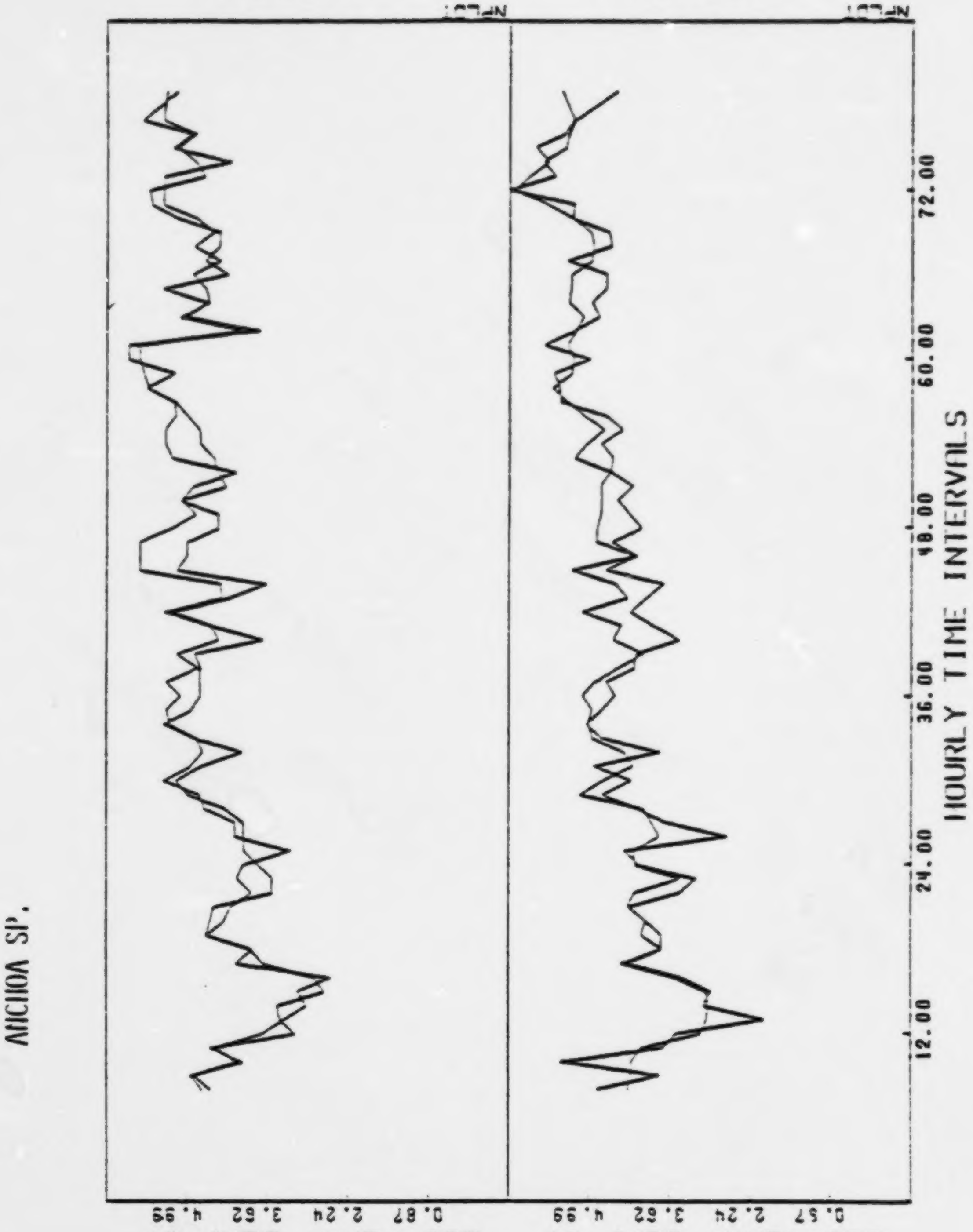

BREVOORTIA TYRANNUS
NORTH
SOUTH
NPLOT
NPLOT
LOG (EGGS DEN. +1)
1.70
3.91
6.11
8.31
LOG (EGGS DEN. +1)
1.70
3.91
6.11
8.31
HOURLY TIME INTERVALS
12.00
24.00
36.00
48.00
60.00
72.00

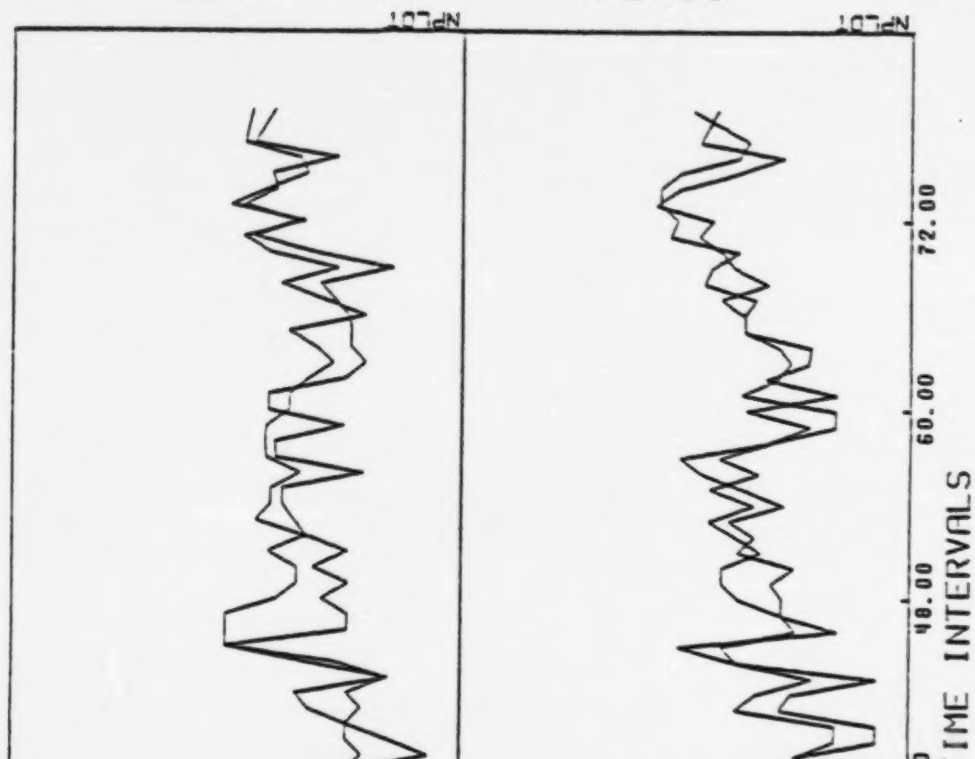
ETROPUS MICROSTOMUS



ANCHOA HEPSETUS

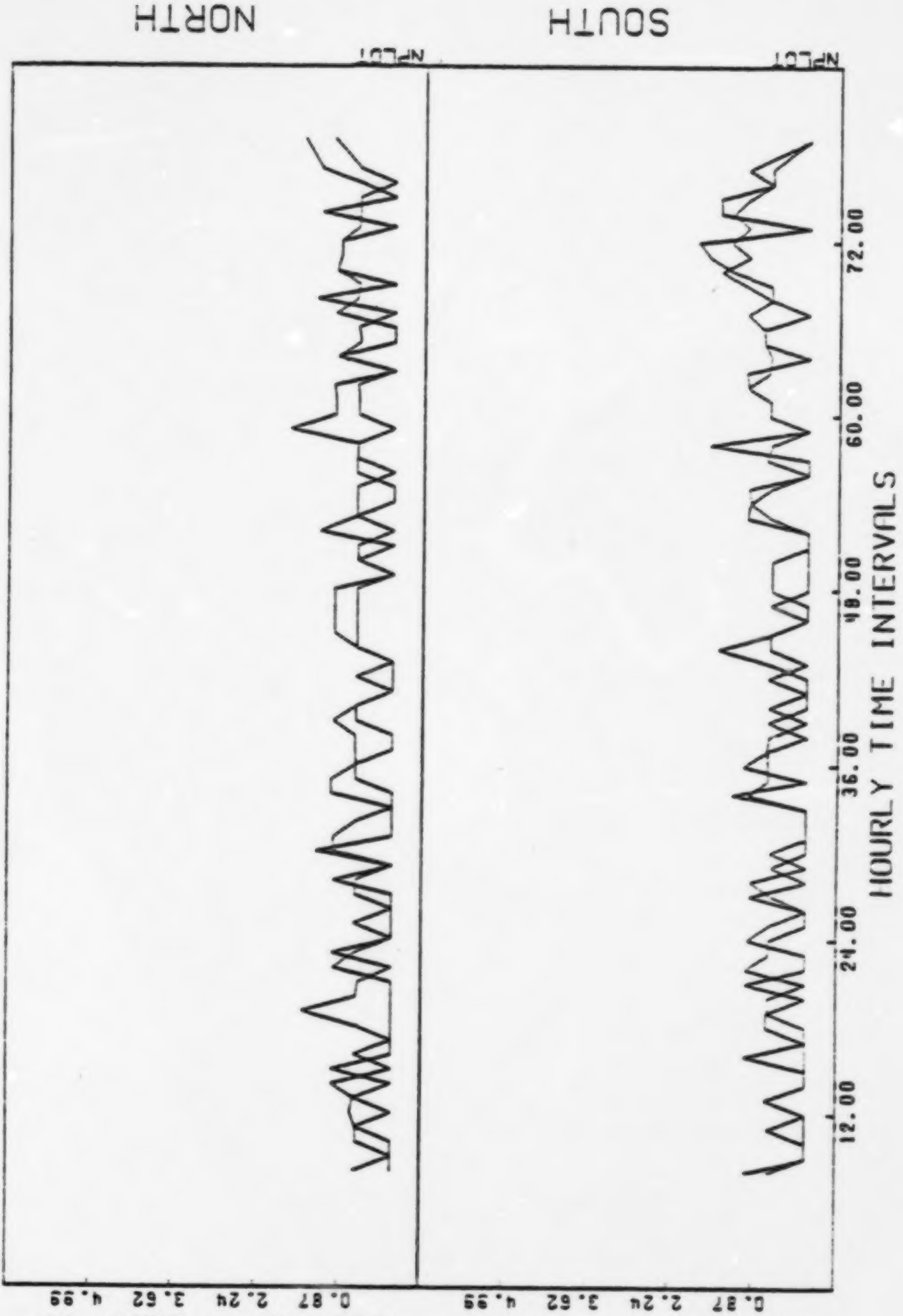



ANCHOA SP.
NORTH
SOUTH
NPLOT
NPLOT
LOG (LARV DEN.+1)
4.99
3.62
2.24
0.87
LOG (LARV DEN.+1)
4.99
3.62
2.24
0.57
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

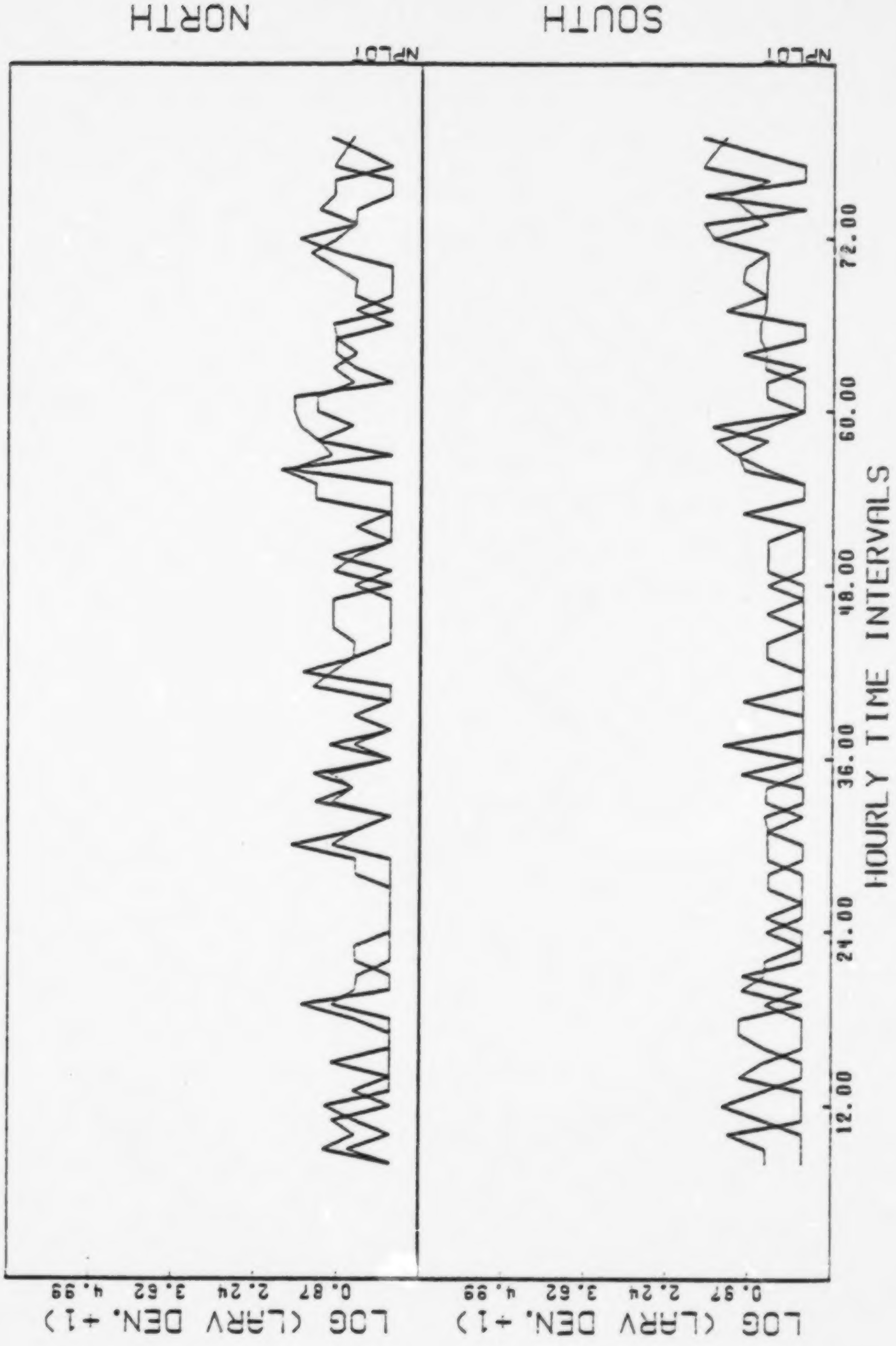


GOBIOSOMA GINSBURGI

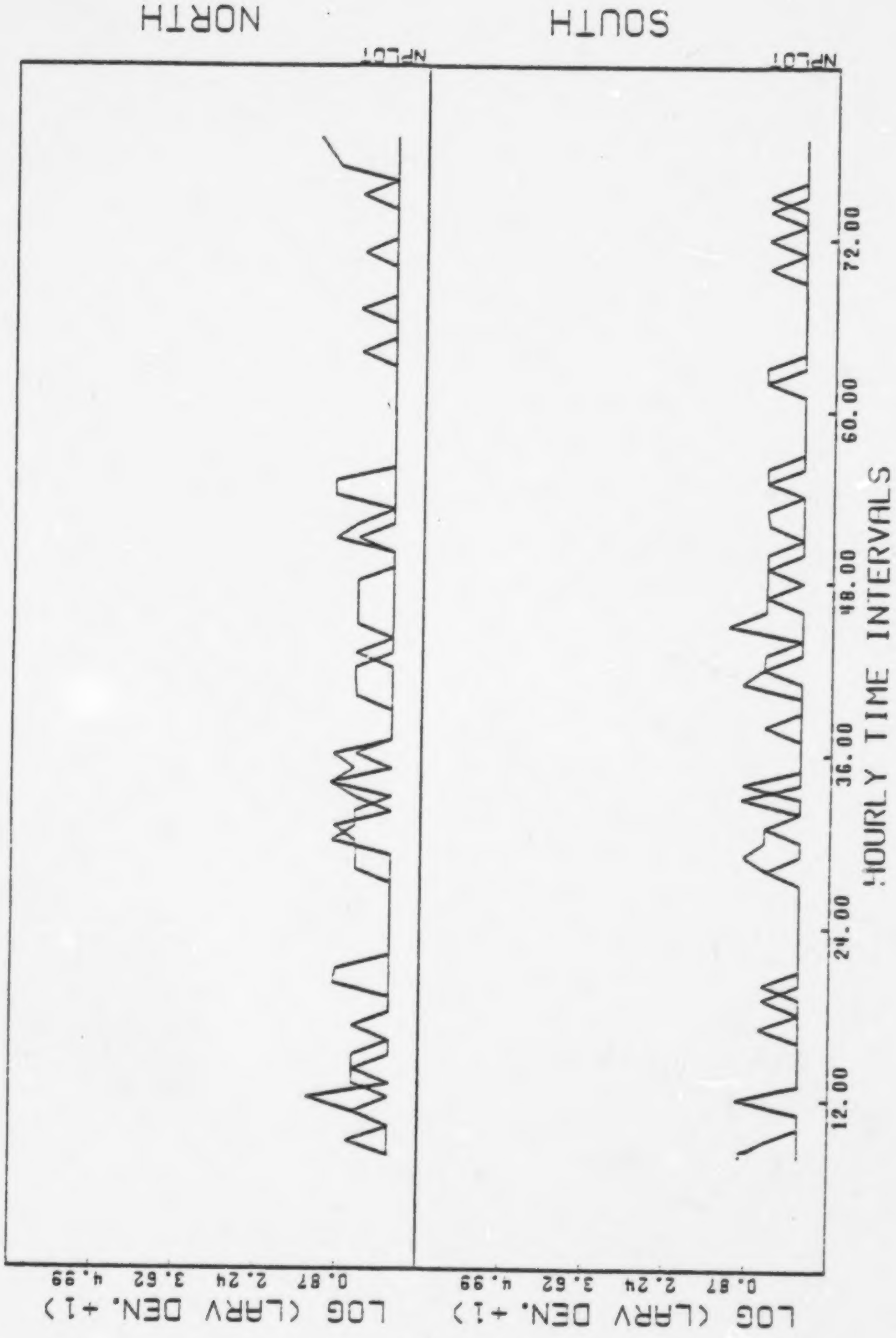
SCOPTHALMUS AQUOSUS



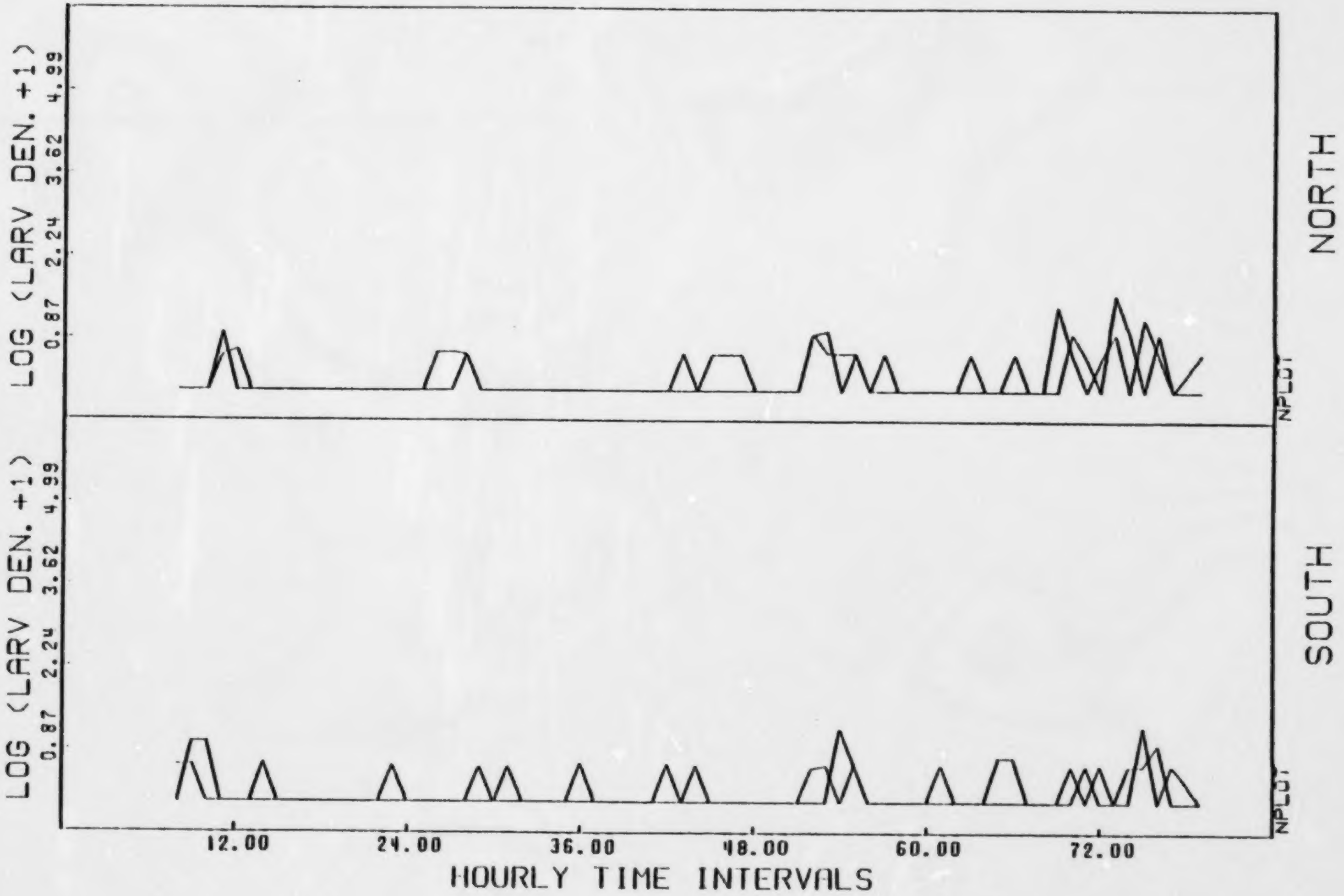
TAUTOGA ONITIS



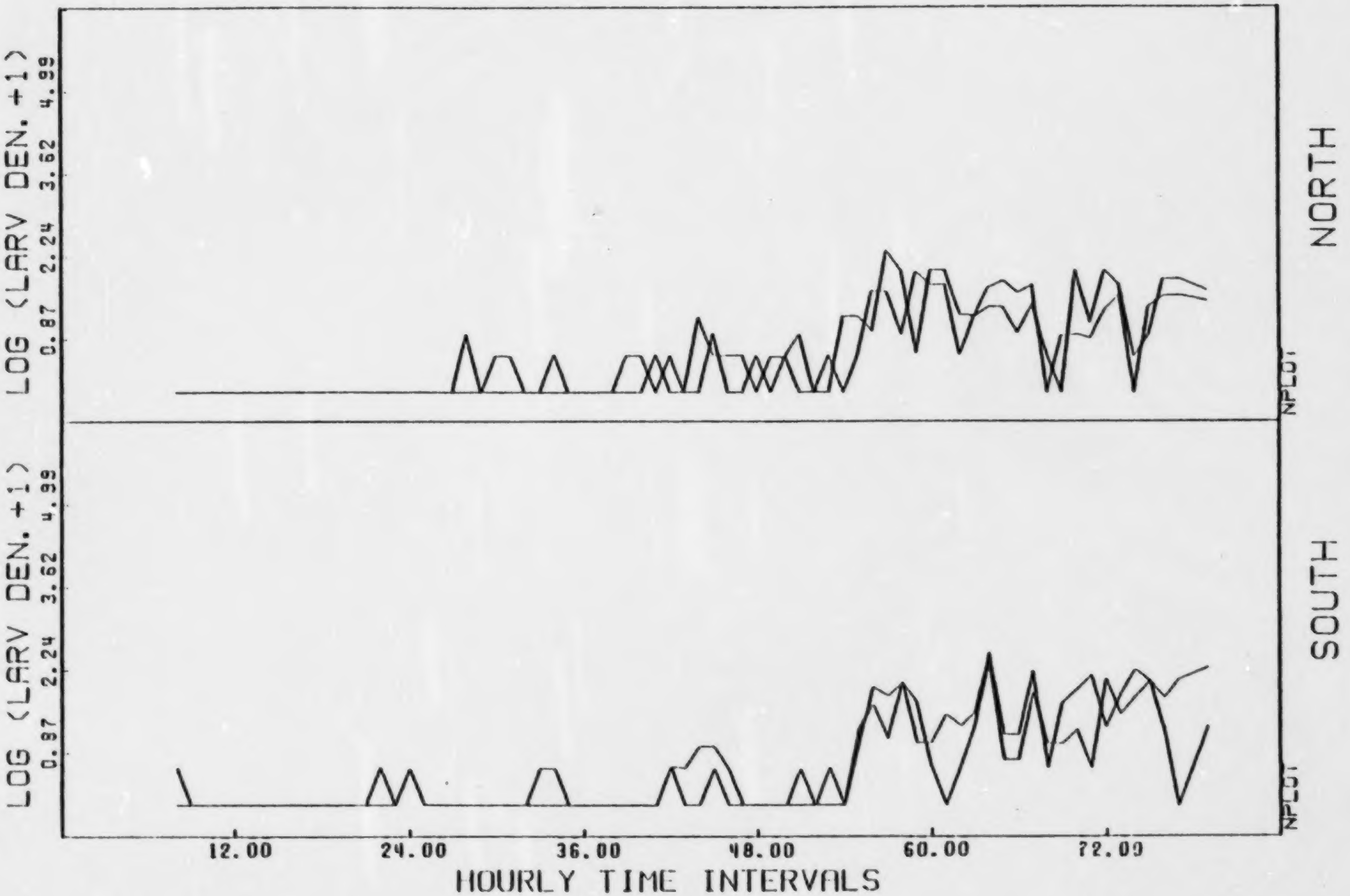
MERLUCCIUS BILINEARIS



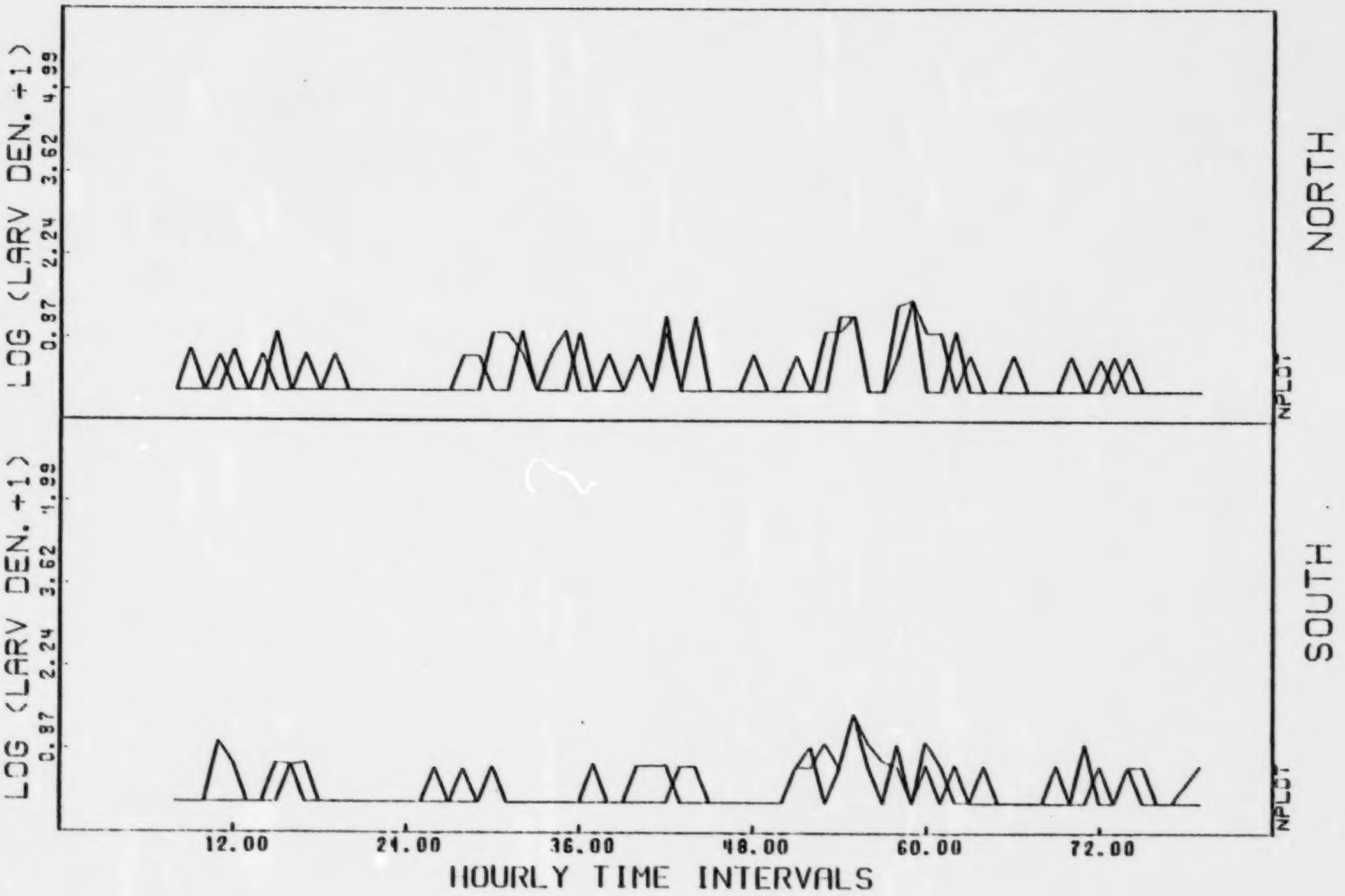
MENIDIA SP.


LOG (LARV DEN. +1)
0.87
2.24
3.62
4.99
NORTH
SOUTH
NPLOT
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

TAUTOGOLABRUS ADSPERSUS

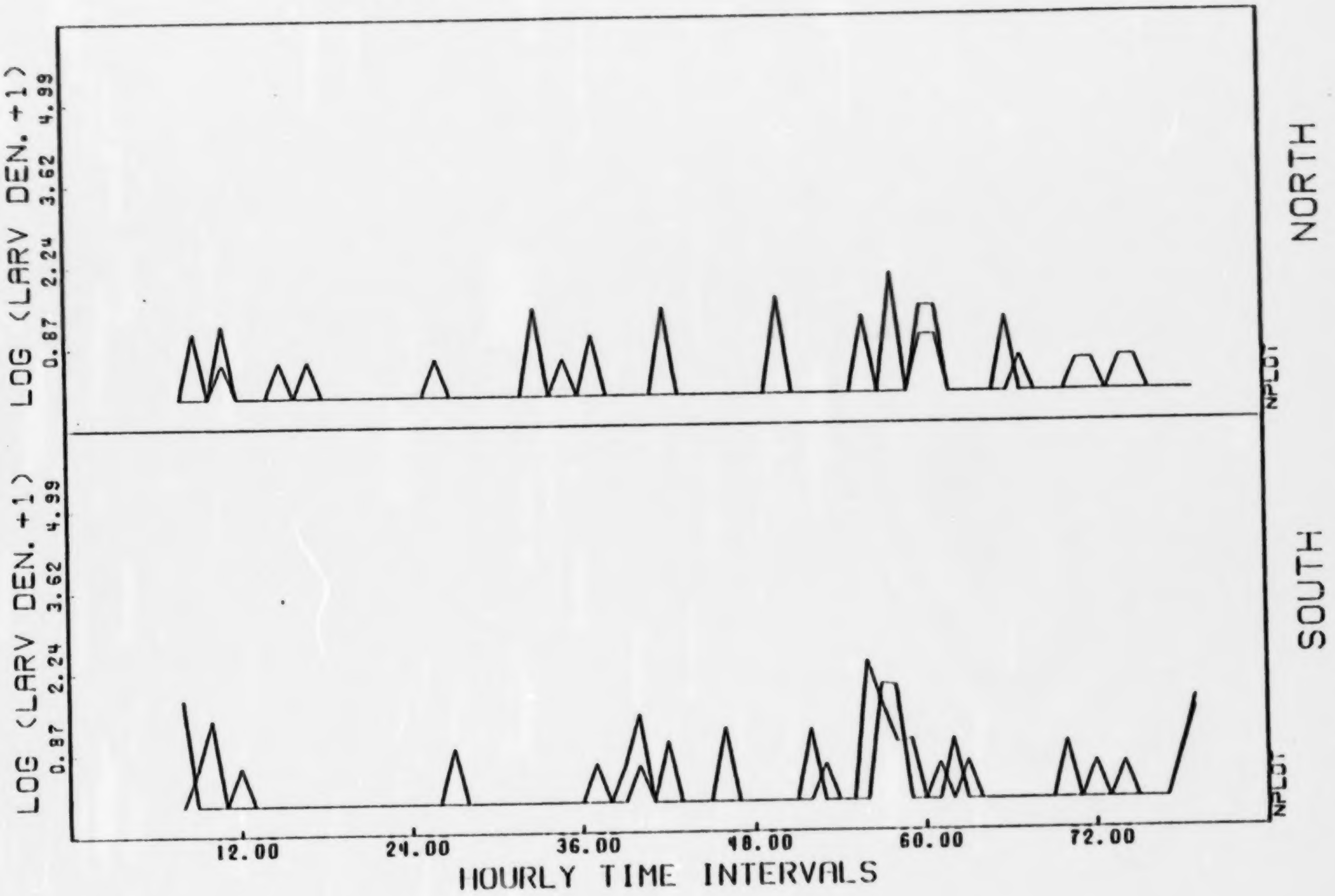


TRINECTES MACULATUS

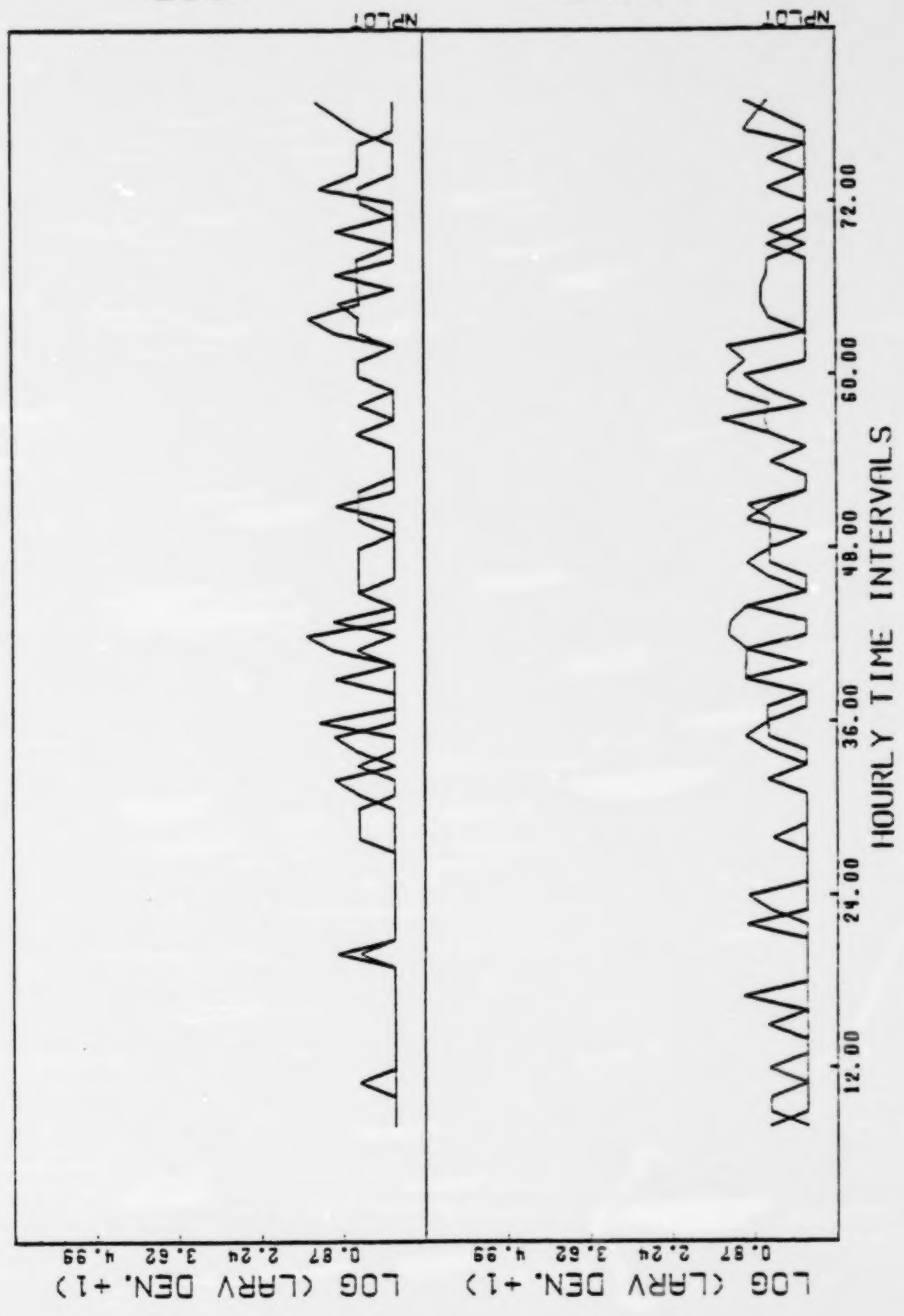


IV-2T

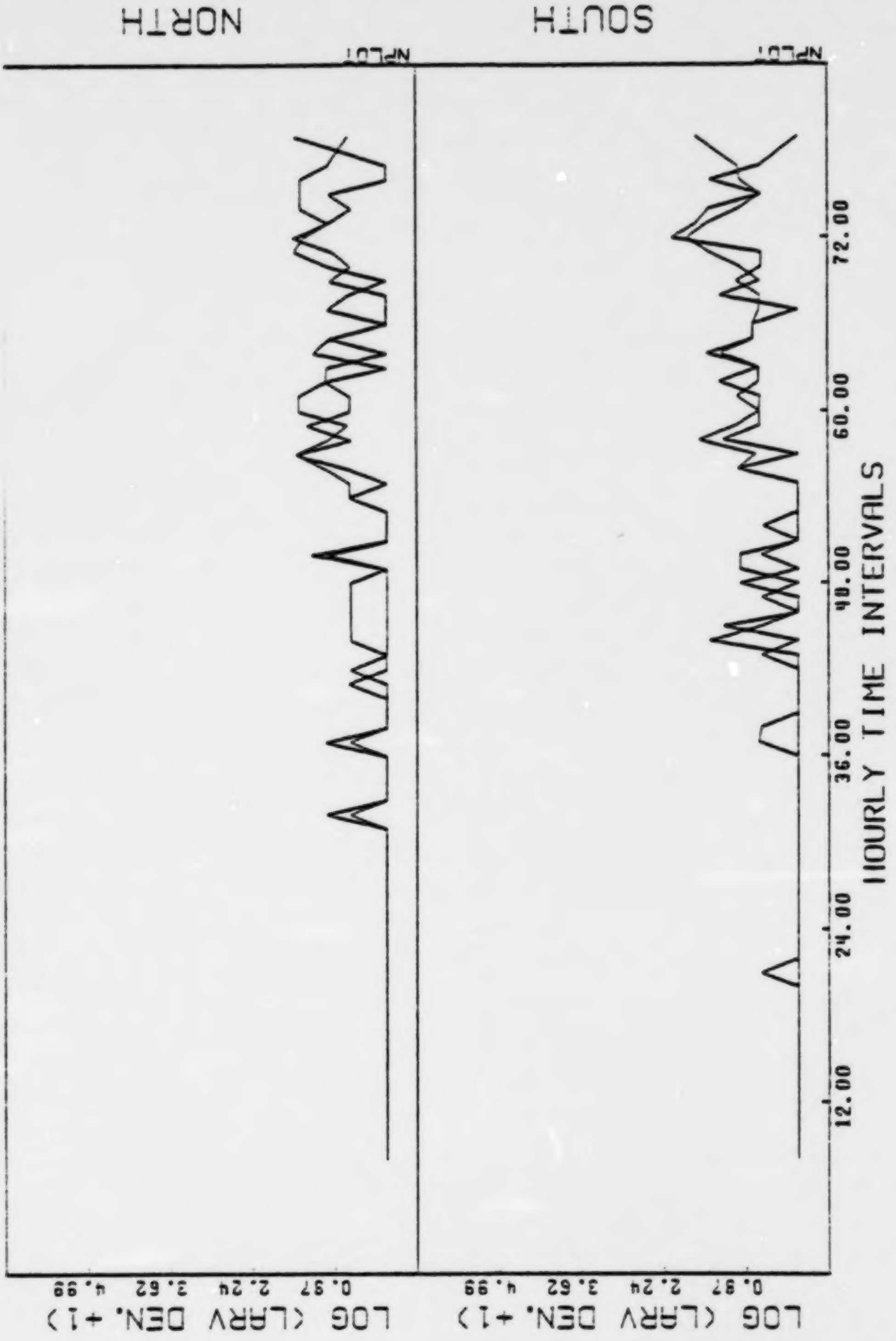
CLUPEIDAE

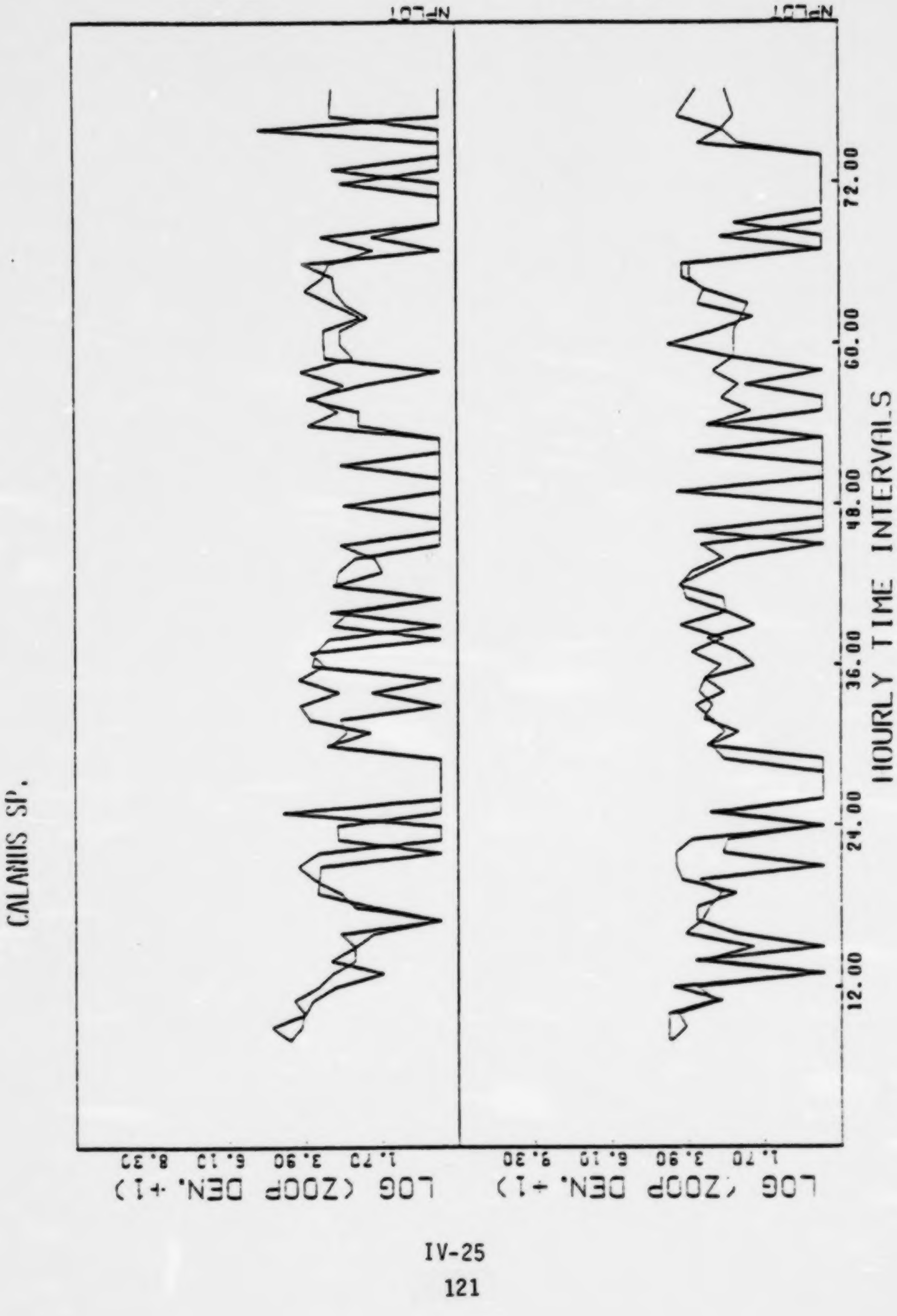

NORTH
SOUTH
LOG (LARV DEN. +1)
0.87
2.24
3.62
4.99
LOG (LARV DEN. +1)
0.87
2.24
3.62
4.99
NPLOT
NPLOT
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

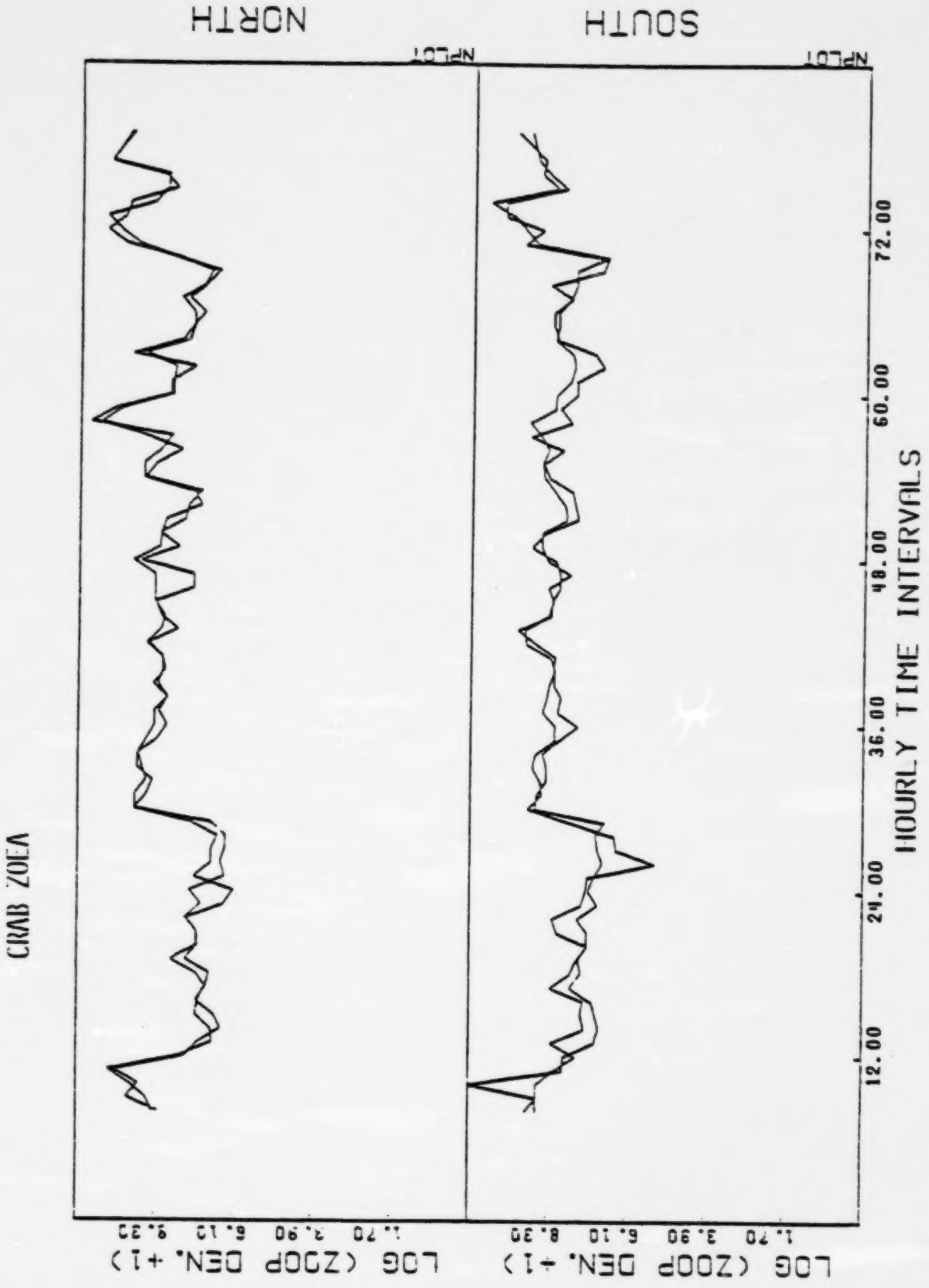
SYNGNATHUS FUSCUS

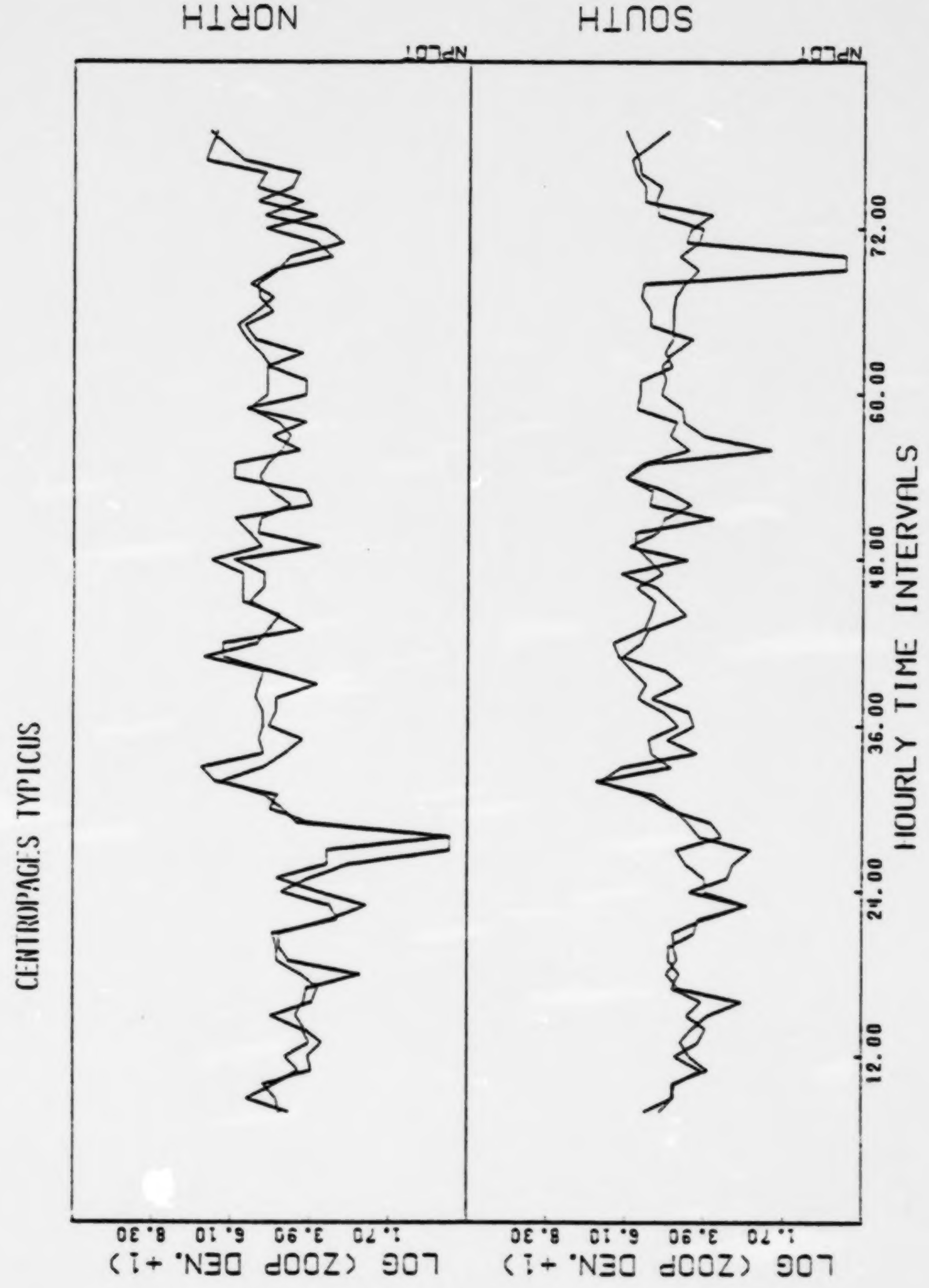


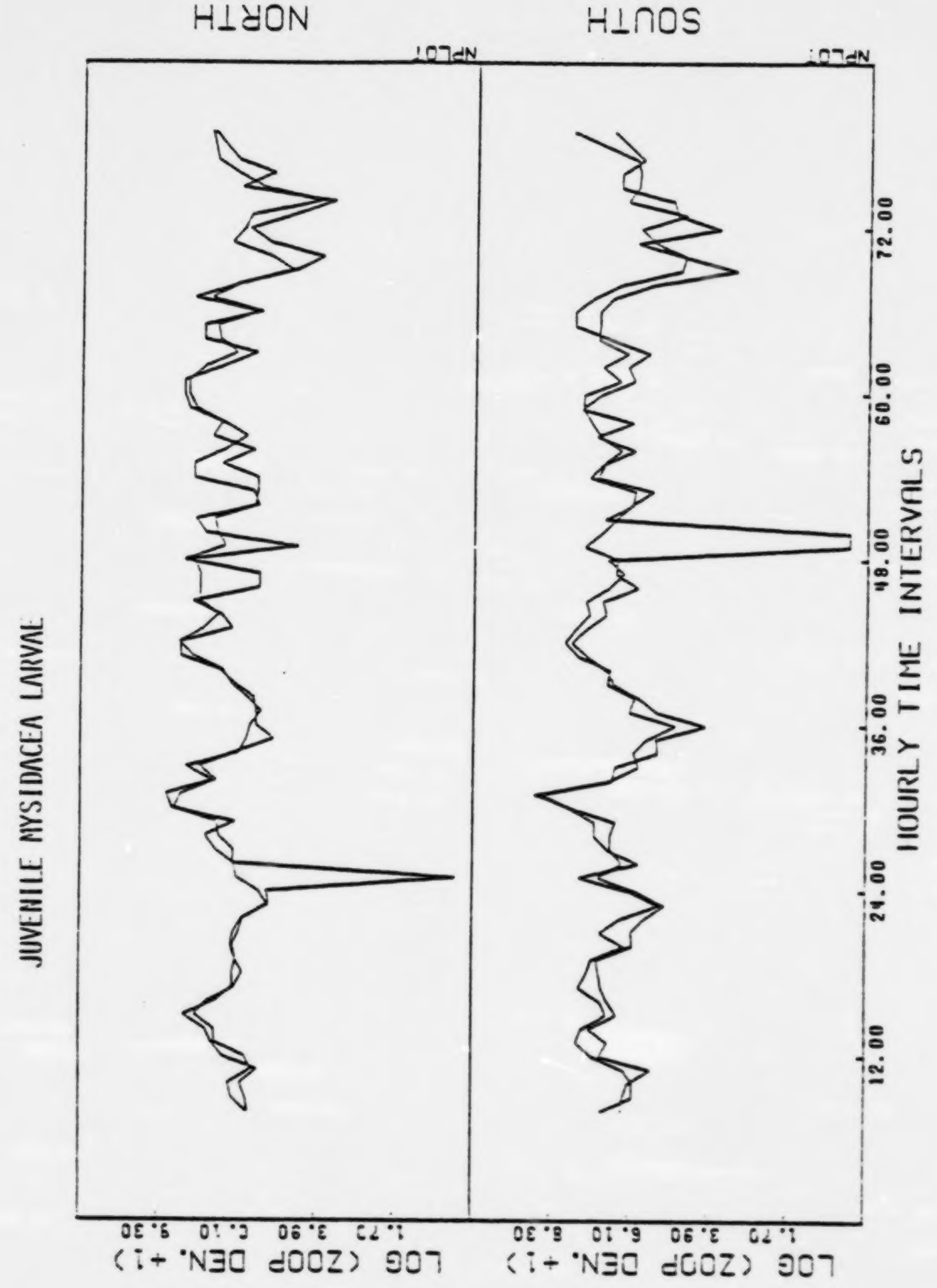
STENOTOMUS CHRYSOPS



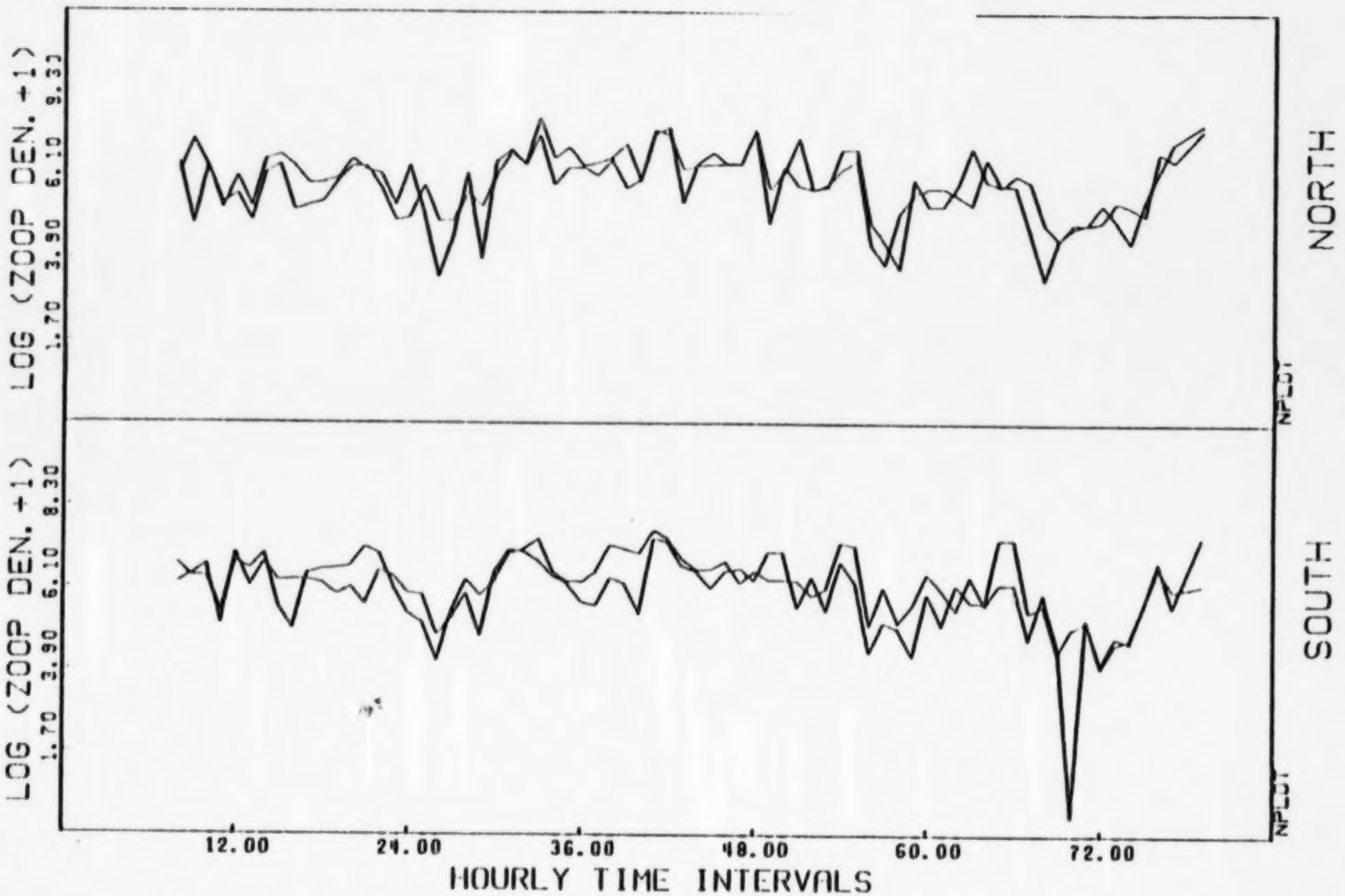

CALANUS SP.
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
1.70 3.90 6.10 8.30
LOG (ZOOP DEN.+1)
1.70 3.90 6.10 9.30
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS


CRAB ZOEA
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
HOURLY TIME INTERVALS
12.00
24.00
36.00
48.00
60.00
72.00

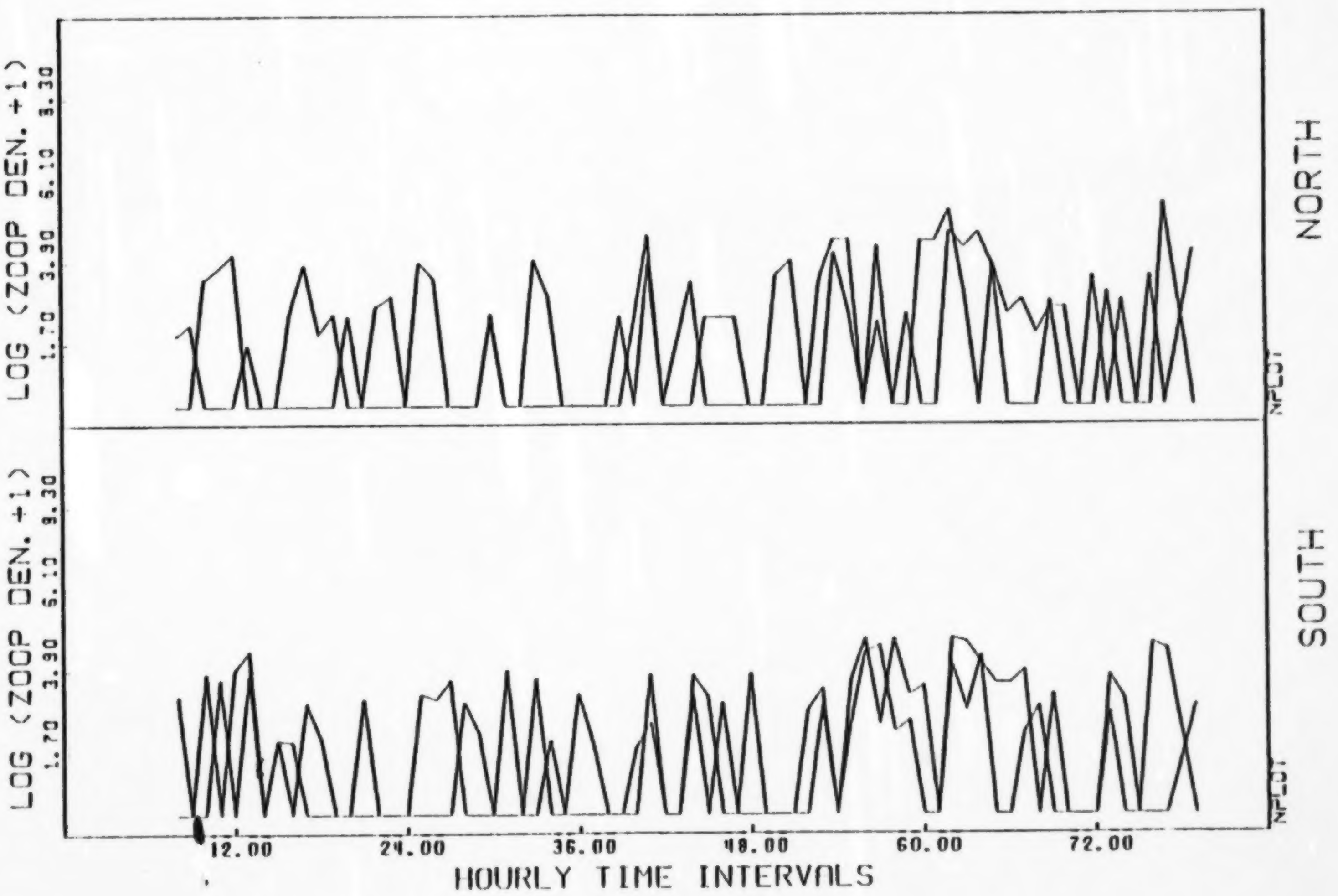

CENTROPAGES TYPICUS
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
1.70
3.90
6.10
8.30
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

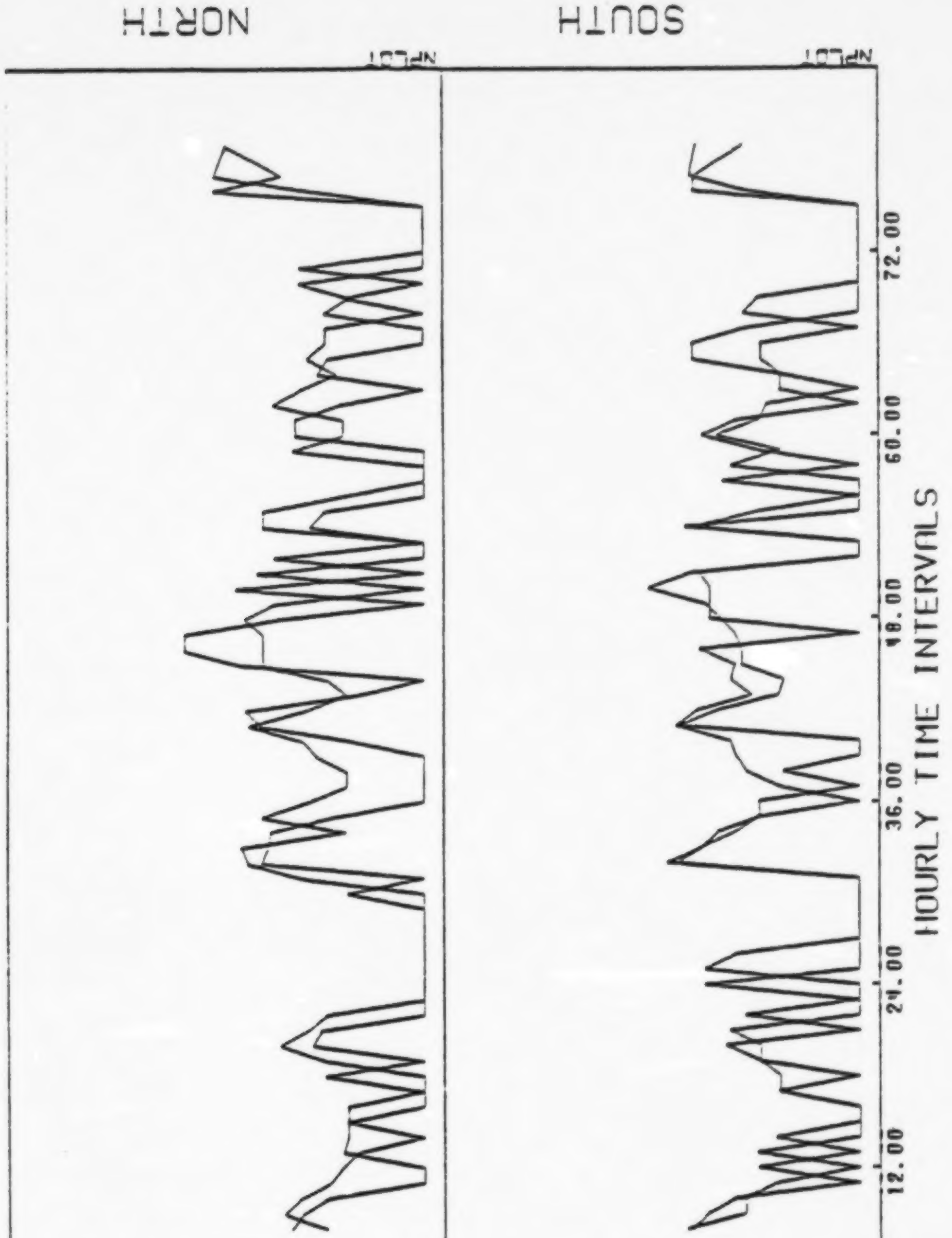

JUVENILE MYSIDACEA LARVAE

TORTANUS DISCAUDATUS

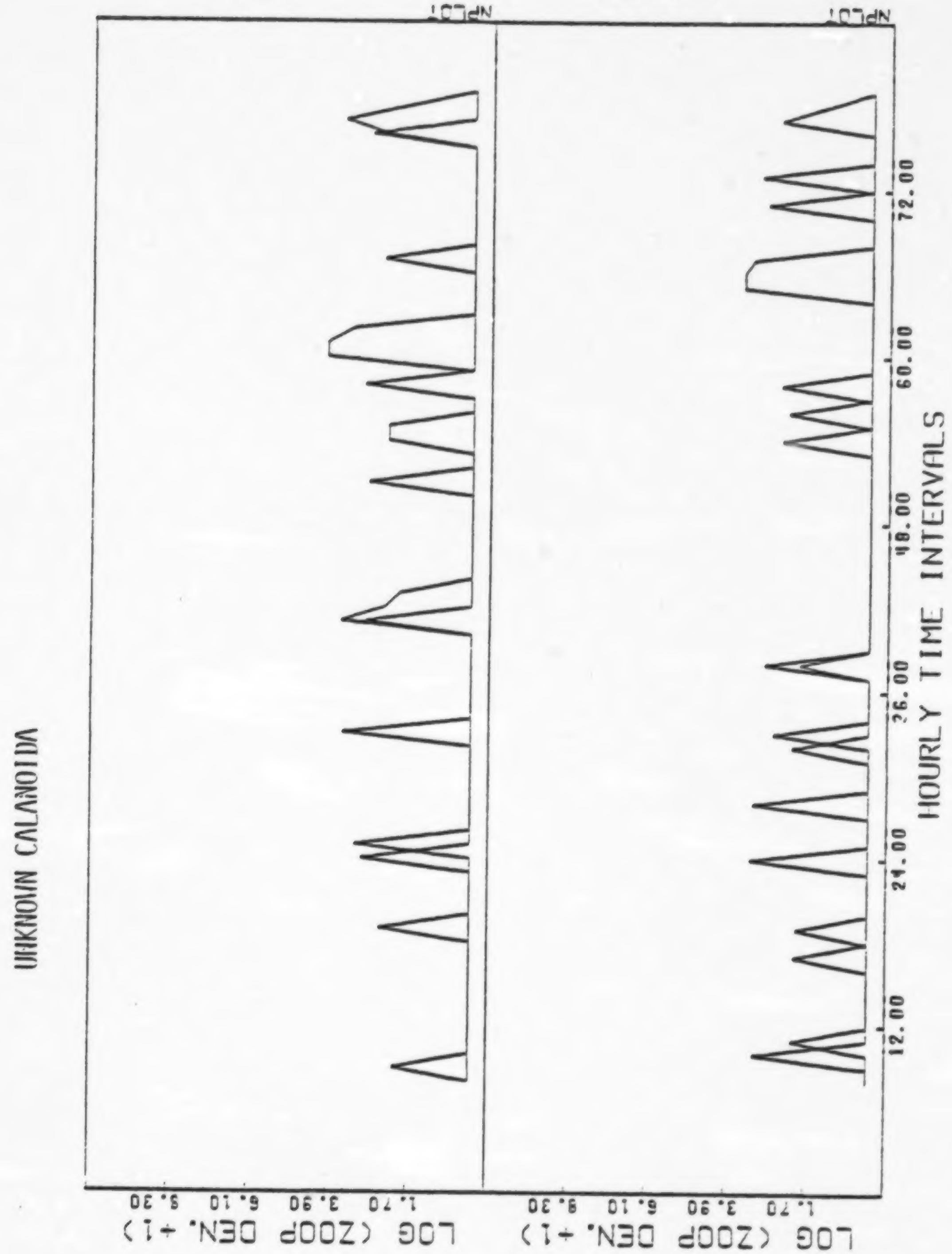


CENTROPAGES SP.



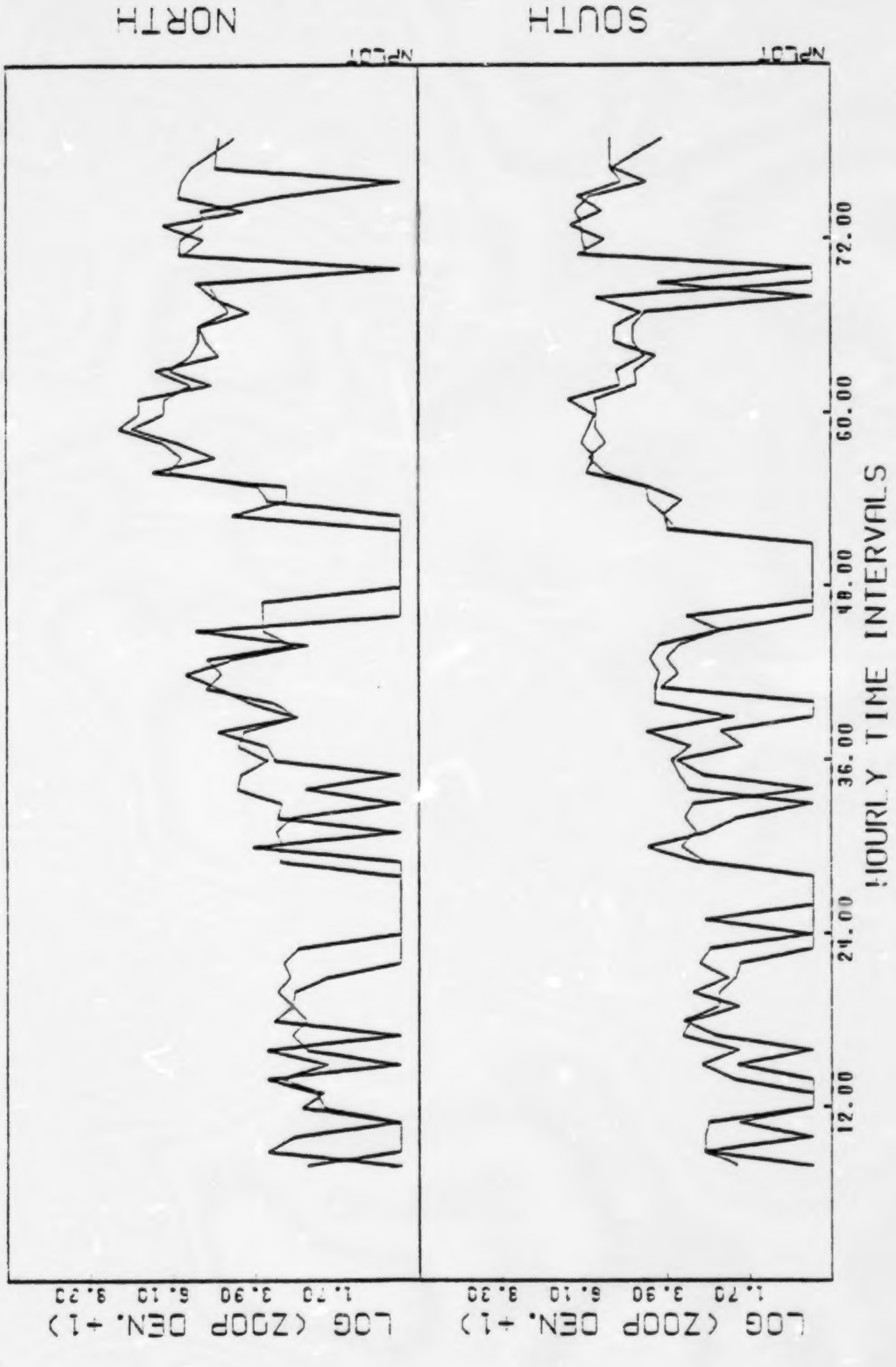


TEMORA LONGICORNIS

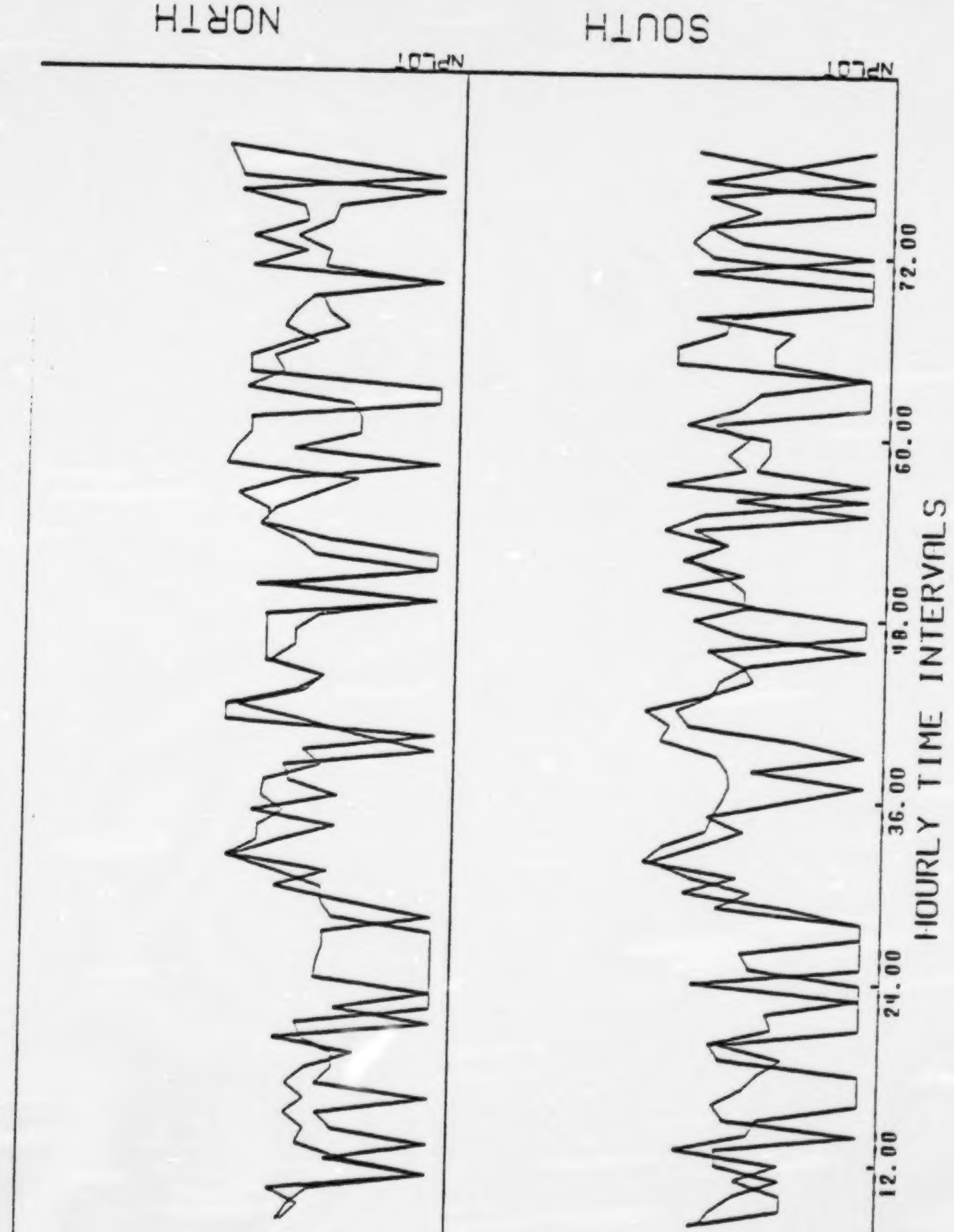


UNKNOWN CALANOIDA

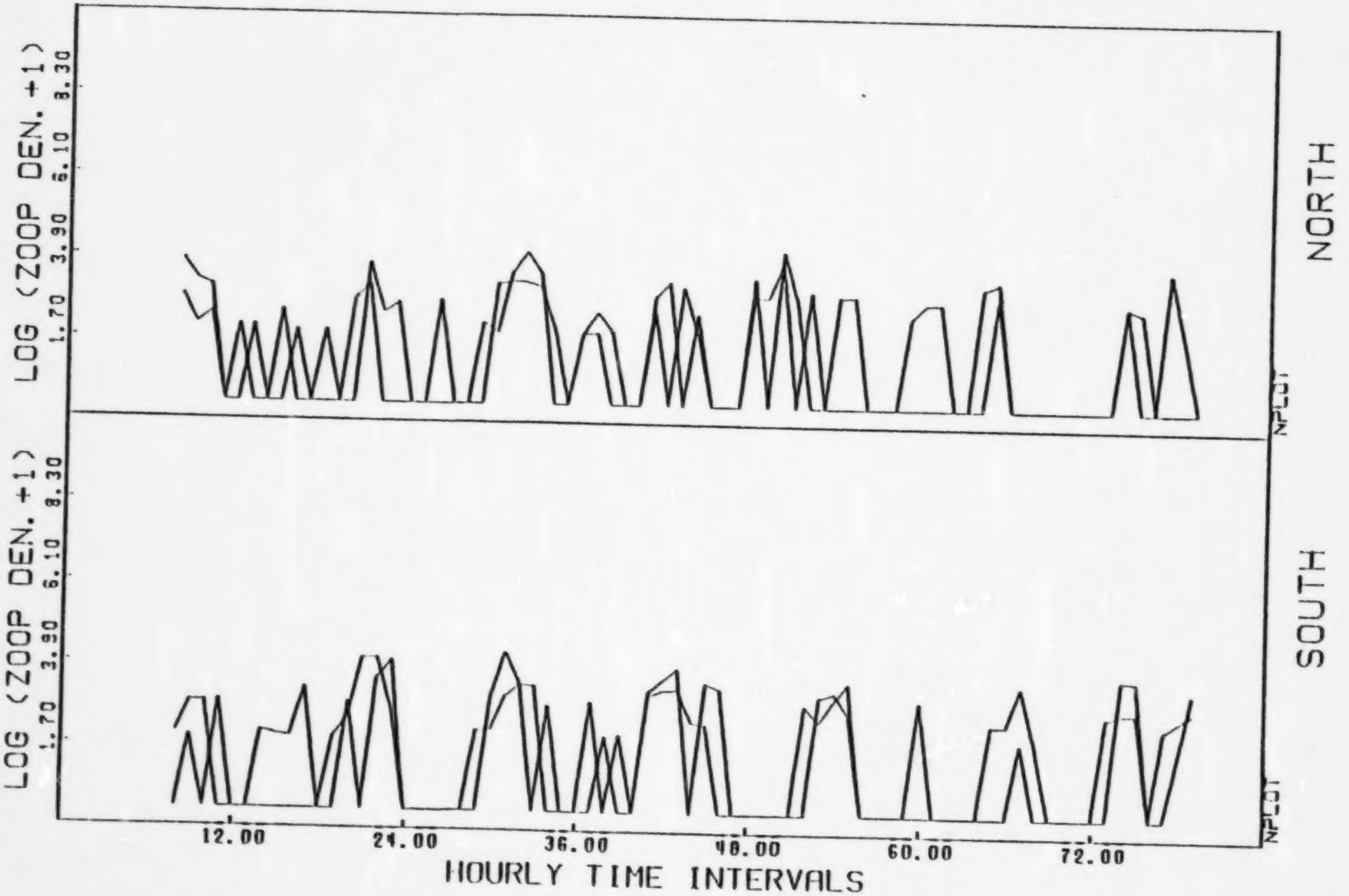
UNKNOWN MEDUSOID

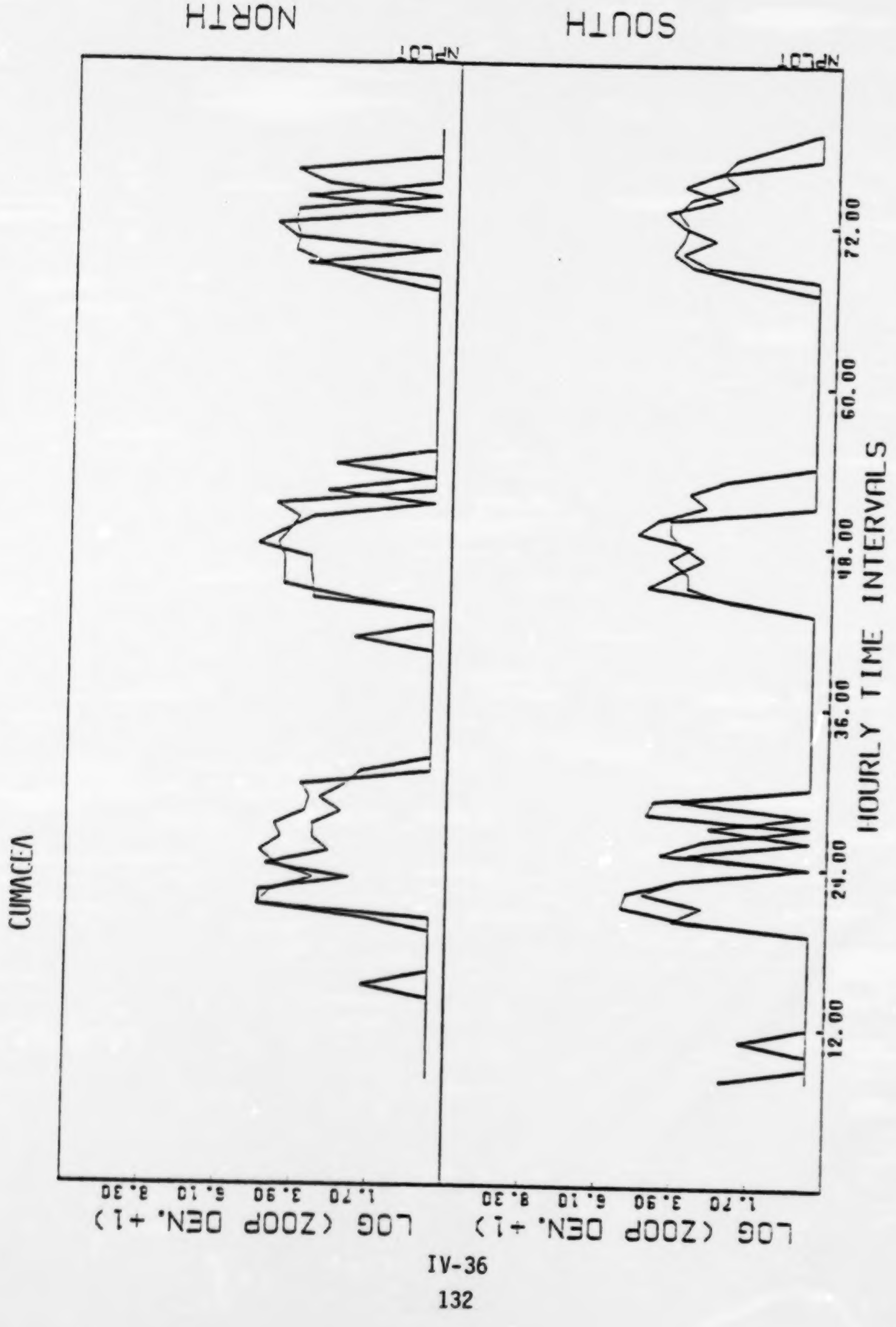


CENTROPAGES HAMATUS

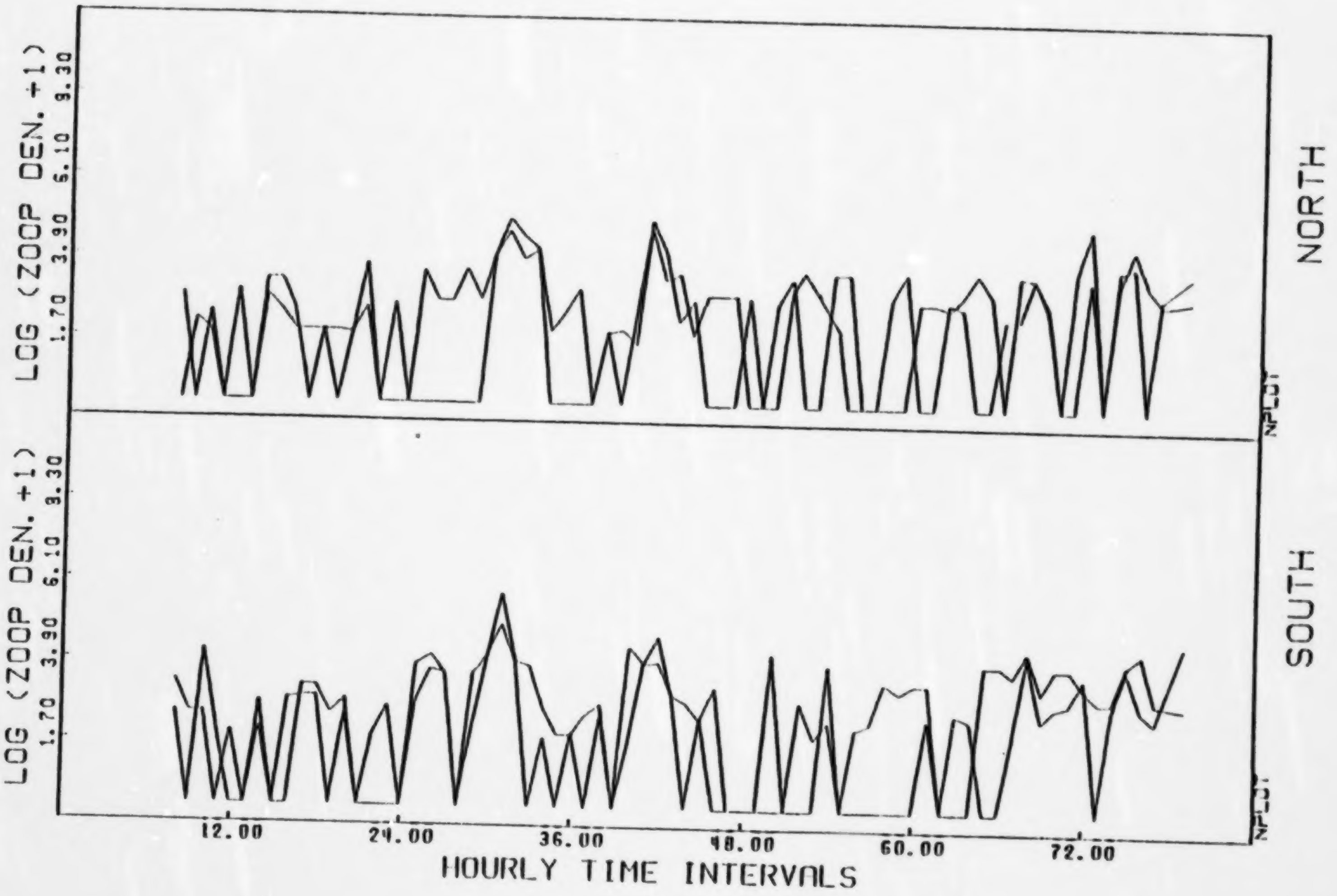


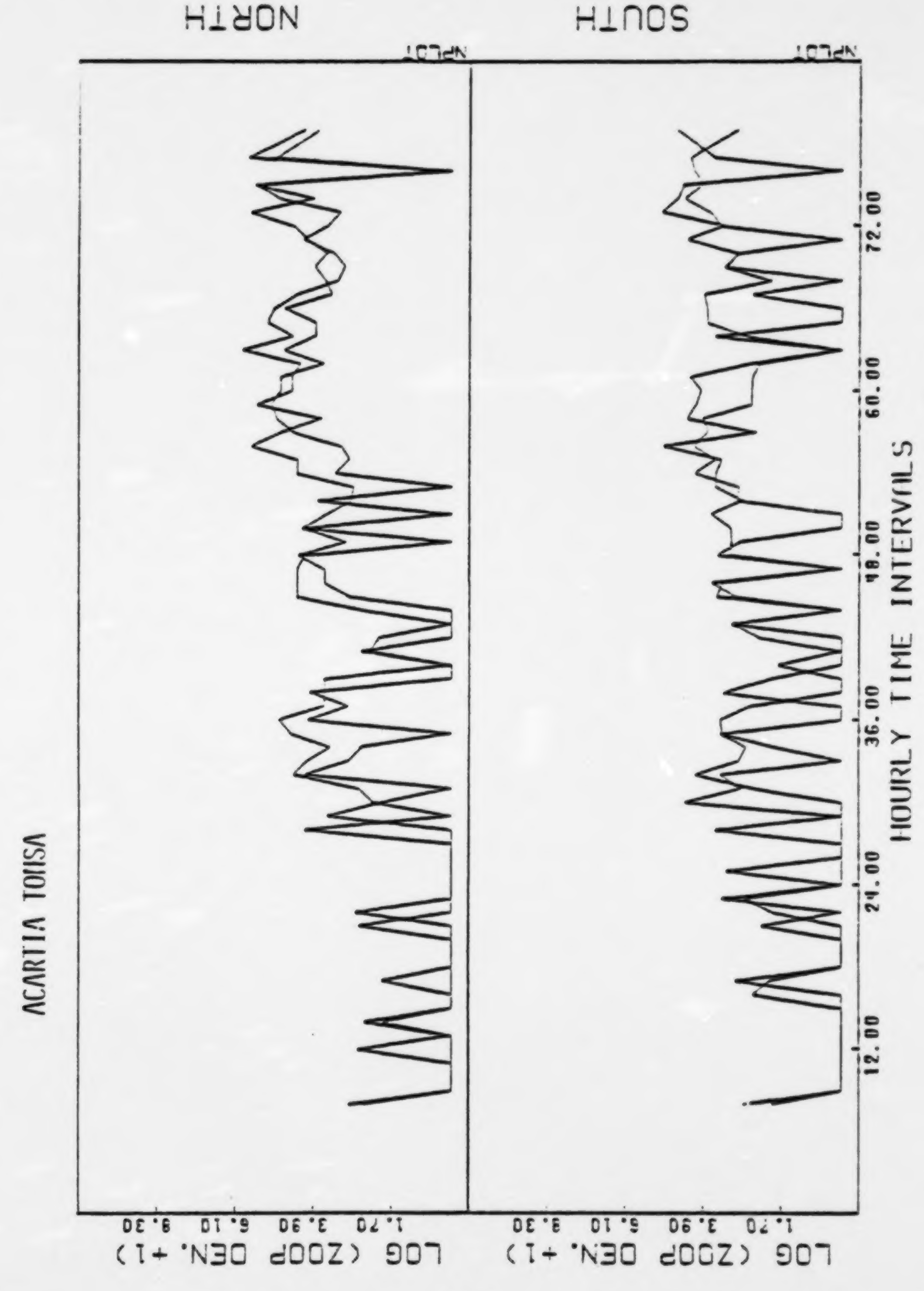
UNKNOWN CEPHALOPODA

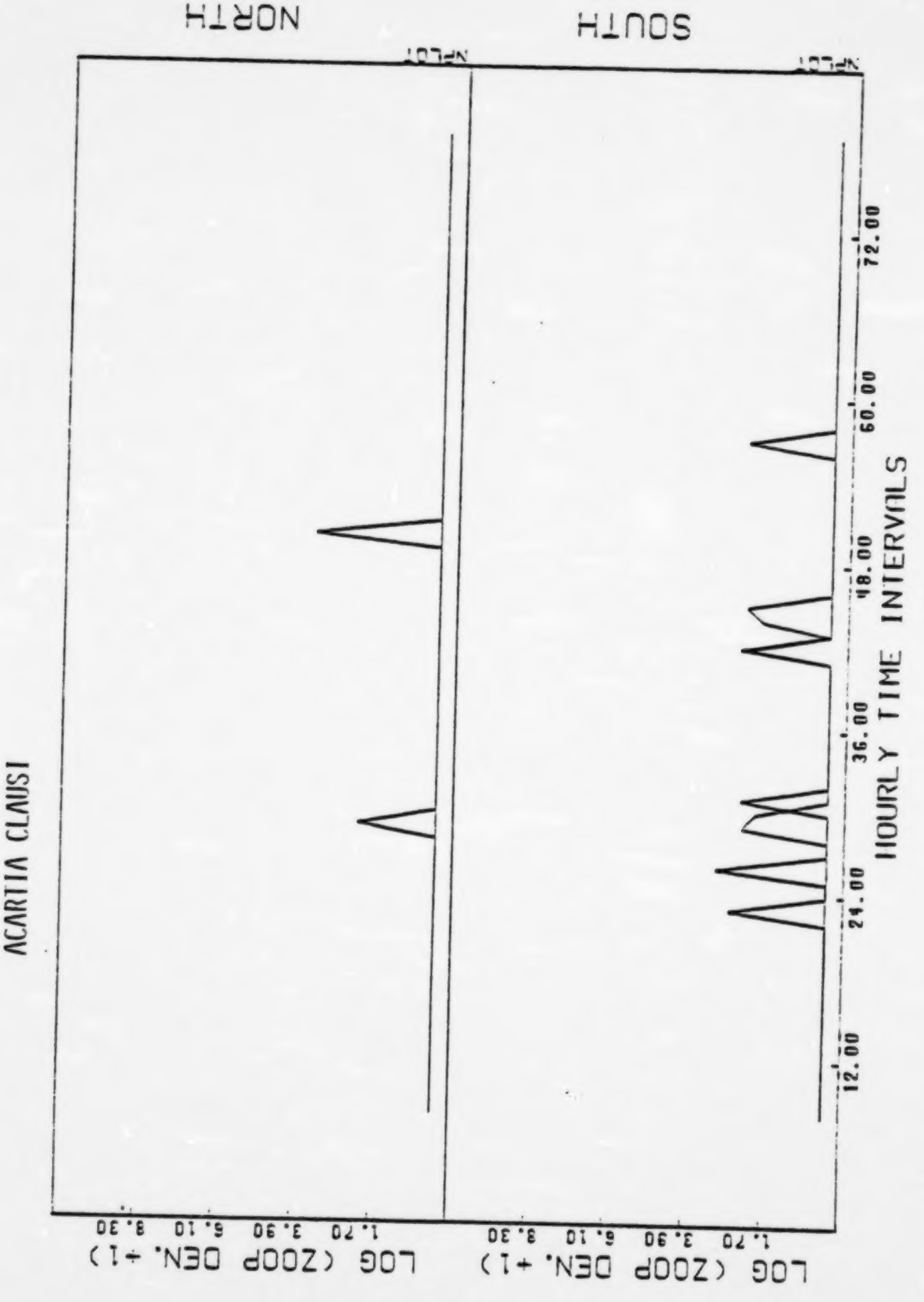



CUMACEA
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

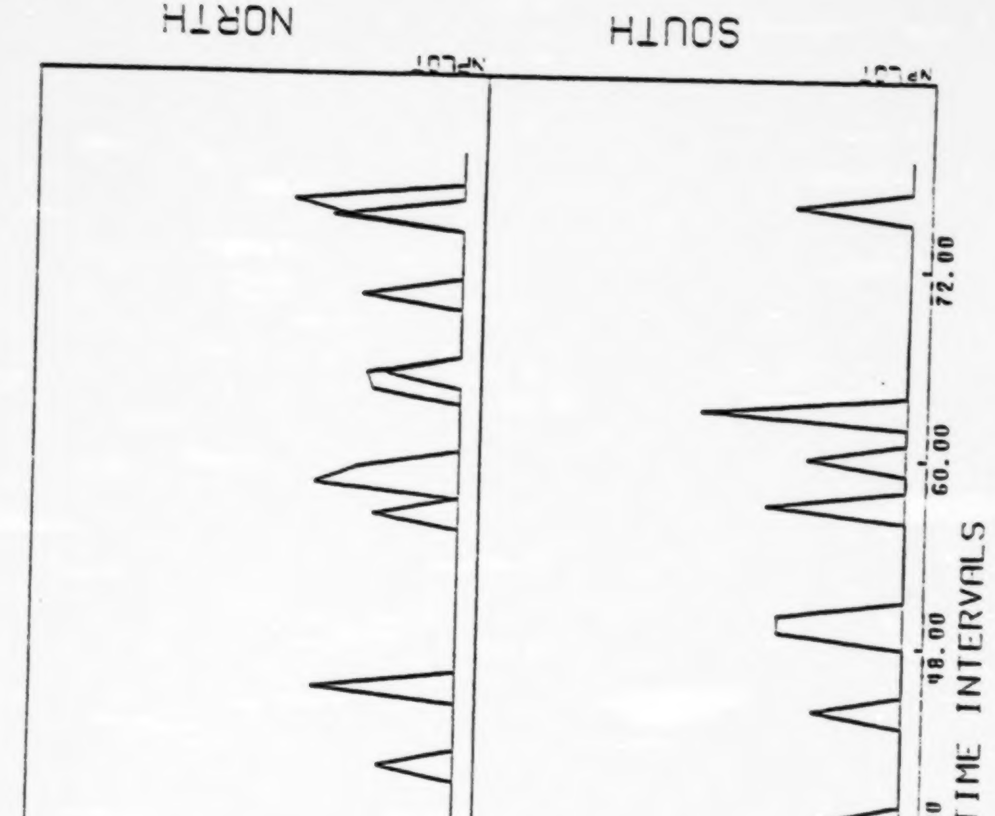
LABIDOCERA AESTIVALUS

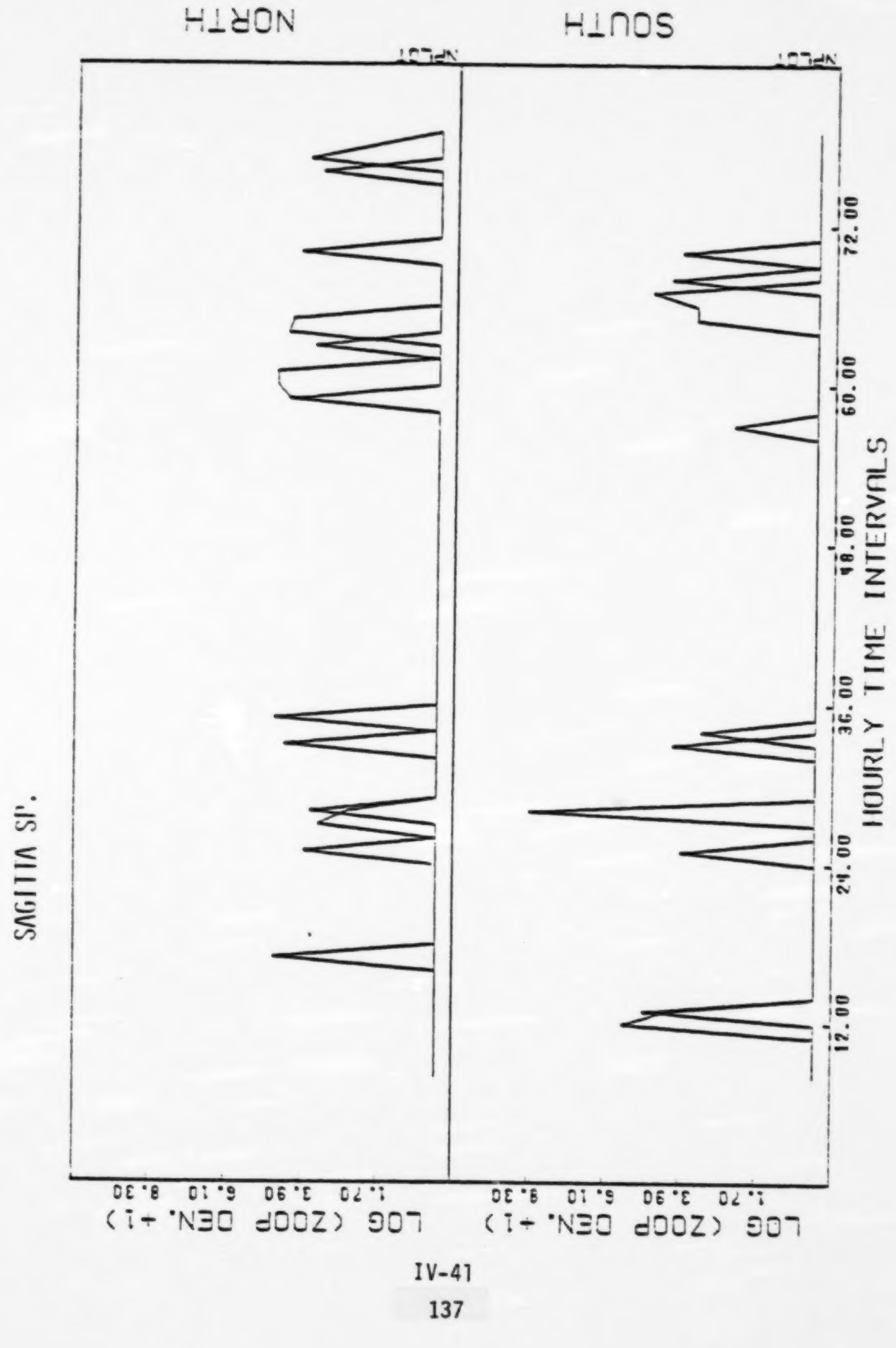



ACARTIA TONSA
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS

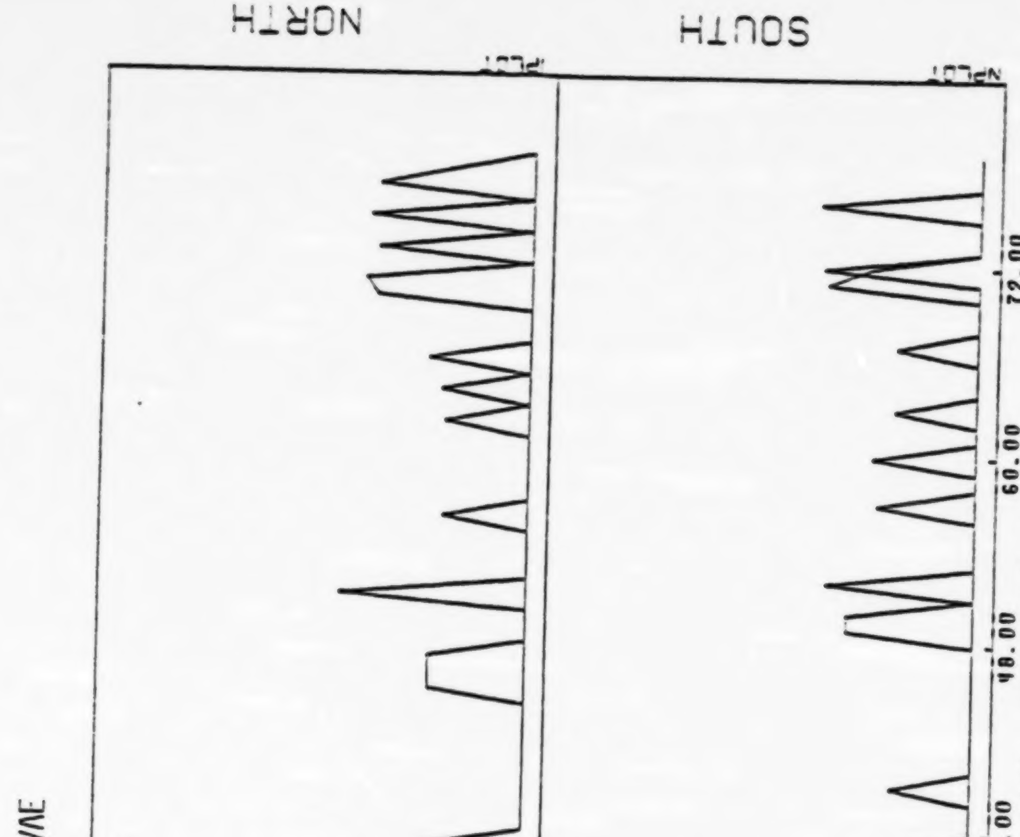

ACARTIA CLAUSI
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN. +1)
1.70
3.90
6.10
8.30
LOG (ZOOP DEN. +1)
1.70
3.90
6.10
8.30
HOURLY TIME INTERVALS
12.00
24.00
36.00
48.00
60.00
72.00

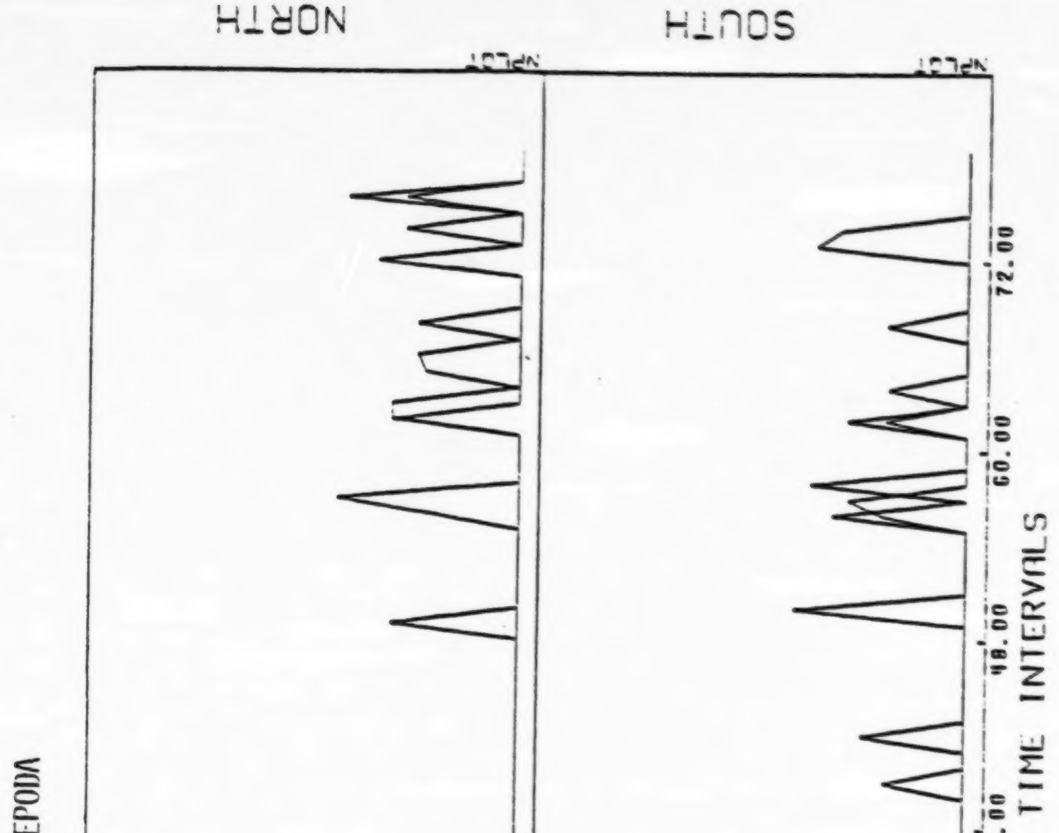
ACARTIA SP.

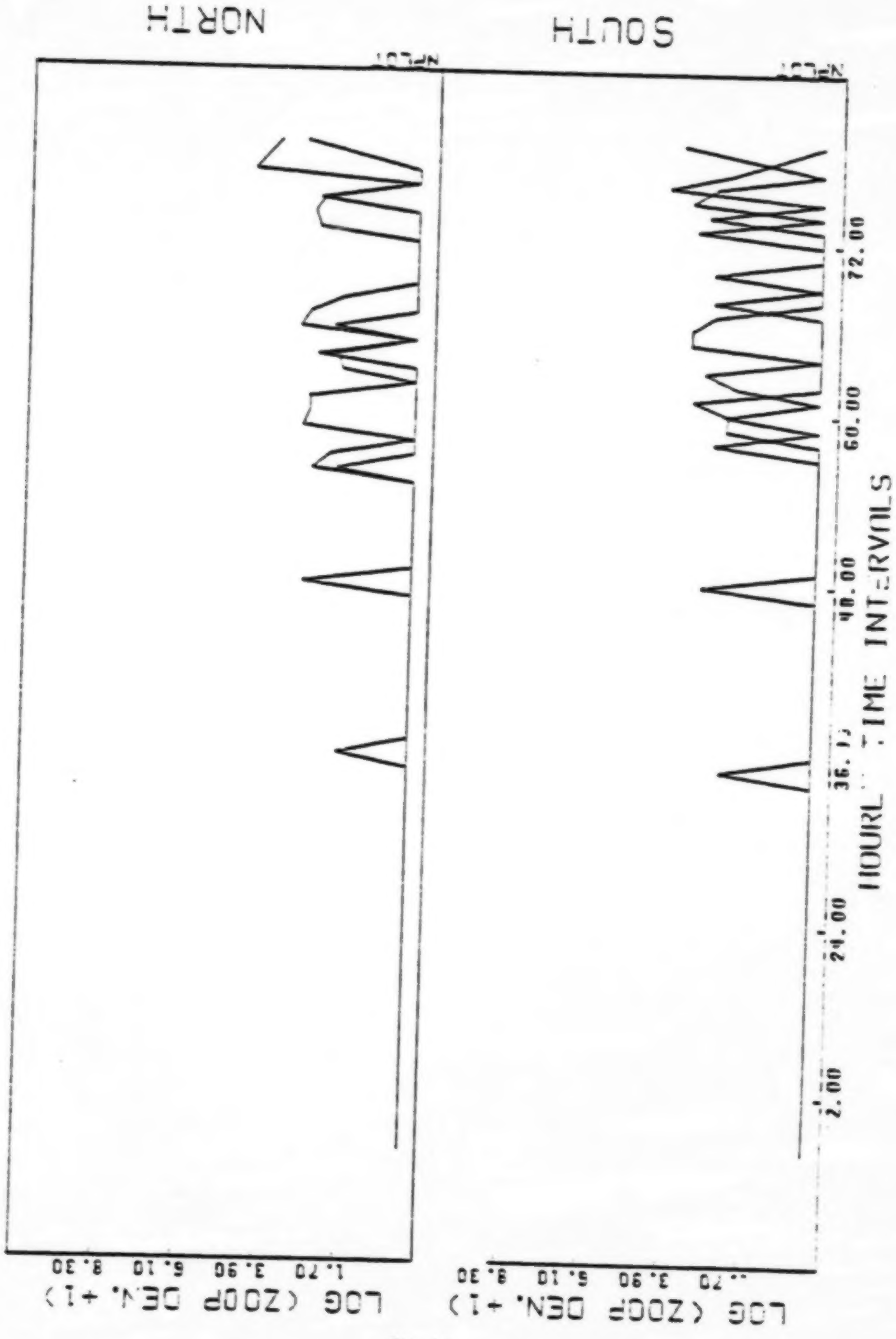

NORTH
NPLOT
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
SOUTH
NPLOT
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS


SAGITTA SP.

NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
1.70
3.90
6.10
8.30
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS


POLYCHAETA LARVAE
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
HOURLY TIME INTERVALS
12.00
24.00
36.00
48.00
60.00
72.00


UNKNOWN ADULT COPEPODA
NORTH
SOUTH
NPLOT
NPLOT
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
LOG (ZOOP DEN.+1)
1.70
3.90
6.10
8.30
12.00
24.00
36.00
48.00
60.00
72.00
HOURLY TIME INTERVALS



STOMATOPODA LARVAE

GASTROPODA LARVAE